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THE WHEEL-POINT METHOD OF SURVEY AND MEASUREMENT OF SEMI-OPEN GRASSLANDS AND KAROO VEGETATION IN SOUTH AFRICA

By

C. E. M. TIDMARSH and C. M. HAVENGA

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NOTE.

Because of the slight distortion of the squared background in some of the graphs, care must be taken in interpreting border-line readings.

On page 17 of this Memoir mention is made of the possible influence of the diameter of the sampling spoke on the estimates of cover obtained from the survey. Since going to press, further information on this aspect has been obtained, and the authors wish therefore to give notice here of their intention to prepare a second paper for publication on this subject. This will include a description of a technique by which the values of the estimates of cover obtained from a survey with the wheel apparatus may be reduced to those of a true point survey. A description will also be furnished of a method of deriving, from the same data, the numbers and mean diameters of the individuals of the various species of plants comprising the population surveyed.

and

C. M. Havenga, M.Com. (Pretoria)

Statistician, Grootfontein College of Agriculture.

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THE WHEEL-POINT METHOD OF SURVEY AND MEASUREMENT OF SEMI-OPEN GRASSLANDS AND KAROO VEGETATION IN SOUTH AFRICA

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FOREWORD.

The quantitative analysis of plant communities is an important aspect of plant ecology. Most recognised methods of determining the cover and composition of vegetation are slow and laborious. Where it is desired to survey large expanses of range land or veld, as in the Union of South Africa, there has been a pressing demand for a more rapid and simple method of obtaining accurate quantitative data. Various attempts to this end have been made, especially by American ecologists. Some of these have proved of considerable assistance, but most are open to criticism on the score of subjectivity.

Any method of survey to be generally acceptable must be objective and yield essentially the same results in the hands of different workers. The wheel-point method evolved by Dr. Tidmarsh and Mr. Havenga fulfil these requirements. Developed on the principle of the point-sample, the wheel-point method is simple, rapid and economical in its demands of trained personnel. Different from the point-quadrat method which, as generally used, is subject to error in furnishing correlated values and which presents, in addition, the practical difficulty of locating truly random points in the field, the wheel-point method is one of systematic sampling. This field the authors have determinedly entered and, by showing that (subject to certain provisions) a systematic pattern of point samples furnishes results that conform in all respects to the theoretical binomial distribution, they have made a contribution in the field of statistics itself.

For those who are not conversant with the theory of statistics, guidance is given in the practical application and computation of results with the wheel-point method of vegetation analysis. Of special value to the field worker is a set of eighteen graphs prepared for the direct determination of the significance of differences between pairs of comparable values of different surveys. A separate set of these graphs has been printed on stout paper for field use and accompanies the memoir.

The wheel-point method of survey has been used in many surveys in the Union during the past six years and is already attracting attention abroad. It has been adapted to some of the requirements of agronomy in which field there appears to be considerable scope for its use.

The authors are to be congratulated on developing this novel and promising tool for botanical surveys.

R. A. DYER,
Chief, Division of Botany
and
Director, Botanical Survey.

Pretoria,
18th May, 1954.

PREFACE.

In modern scientific research work statistical methods, and in particular sampling survey methods, are applied with increasing success in many different fields. This is a consequence of the fact that modern sampling theory is based on sound scientific foundations, and has become an indispensable tool in all research work dealing with mass phenomena. In many cases a complete survey is impossible as a result of lack of means, time or funds, while the sample survey, properly set up and conducted, can give the results required to a given degree of accuracy and with a minimum of time.

In fields allied to ecology, for example in forestry, sampling surveys have been applied with success, and standardized methods have been developed which comply with the basic theoretical requirements of randomness.

In the particular case of ecological surveys, different methods have in the past been applied with different degrees of success. It appears that the basal cover method gives the most reliable measurement of the cover, but that the most difficult problem, in view of the large areas to be covered, is the randomization of the sample taken.

The authors have replaced random sampling methods by a systematic sampling process by means of their wheel-point method. The two methods mentioned will lead to the same estimates of the population means and standard errors, on the condition that there are no inherent cycles or periods in the population to be sampled.

The basic statistical theory underlying this wheel-point method is elementary. The design of this method, as described by the authors, is sound and will lead to valid results on the above-mentioned condition that cycles or periods in the vegetation are absent.

For some years this method has been applied successfully in surveys of many different types of vegetation. The results have been very consistent in those cases where surveys were made in successive years in similar areas with the same typical vegetation. This empirical test is, of course, most important for the justification of any scientific method.

The authors have done a valuable piece of work in developing a valid method of determining the cover of vegetation for grazing or other purposes.

B. DE LOOR,
Department of Statistics,
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Pretoria, 22 July, 1954.

THE WHEEL-POINT METHOD OF SURVEY AND MEASUREMENT OF SEMI-OPEN GRASSLANDS AND KAROO VEGETATION IN SOUTH AFRICA.

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INTRODUCTION.

In relatively recent years, since the recognition of the study of plant communities as an important branch of botanical science, rapid advances beyond the realm of purely descriptive ecology have been made. With this development, the need for accurate quantitative expression has become increasingly urgent. A number of different methods of survey and measurement have consequently been devised in various attempts to meet the diverse needs and conditions confronting investigators in the field.*

In extensive semi-arid and arid regions in which, though expanses are vast, trained personnel are usually few, and in which, under the impetus of ambitious soil and pasture conservation programmes, experimental ecology, the determination of grazing values and measurement of the vegetal changes of pastoral ranges are making rapid strides, the need for a simple, rapid method of survey and measurement is most pressing.

Of the many techniques devised, the so-called " point " method developed by Levy (1933) appears, in many respects, to hold most promise. Since first developed by Levy, in 1925, the method has become fairly widely used and developed further by various workers.

Like the majority of methods that have so far appeared in the literature however, this method has apparently not yet been fully established biometrically. Crocker and Tiver (1948) have recently reported progress in this direction, and claim that, for Australian grasslands, 300 to 500 point samples per unit area (field or paddock) are usually sufficient for a reasonably accurate determination of the composition of the pasture. In common with other workers, they state that botanical composition expressed in percentage cover is one of the best means of studying ecological changes and trends in development of a pasture.

Penfound (1945), who made studies with quadrats, found that of the three concepts, frequency, density and cover, frequency is the most artificial and least important, whereas cover is the most valuable since it is unaffected by quadrat size and delineates relative dominance better than frequency or density. It remains therefore to decide whether canopy or basal cover should be measured, and what is the most expeditious and reliable method of making the determination.

Since basal cover, i.e. the rooted cover at ground level, is least subject to fortuitous variations according to season, or to the incidence of grazing or other agents of defoliation, and since changes in values in respect of that portion of the vegetation have, therefore, more ecological significance than changes in

* Various techniques at present in use are reviewed by Ashby (1948).

canopy, i.e. the portions of the plants raised above the soil surface, the writers have concluded, in common with other workers, that basal cover is the more useful criterion for the evaluation of the vegetation.

As pointed out by various ecologists, there is in most types of vegetation, other than systematic plantations and row crops, a marked tendency for individuals and species to aggregate in clusters. Thus, if the point method of determination is adopted with the conventional point quadrat frame, or bridge, a high correlation would be expected between the recordings of points within the frame or bridge. This is well illustrated by the data of Crocker and Tiver (1948) who state that species which tend to occur in isolated aggregates may either over-contribute or under-contribute to the final analysis, depending upon whether or not chance samples are taken in the colonies.

In conformance with statistical theory, which requires that the necessary number of sampling points should be distributed independently, at random, over the whole area to be sampled, Corby (1950) concludes from his studies with the point quadrat bridge that the smaller the number of points per bridge, and the greater the number of positions occupied by the bridge, therefore, to furnish the same total number of sampling points, the greater is the accuracy attained; and that finally, by implication, reduction to a single point per bridge, or frame, should furnish the greatest possible accuracy.

Since however, although physically possible, such procedure is usually not readily practicable, especially when large areas have to be sampled, the alternative of a number of points, systematically distributed, has been considered. According to Yates (1949), valid estimates of the population means may be made by this method from which, also, approximate extimates of the sampling error may be obtained, provided the sampling points do not coincide with a natural cycle period of the population to be sampled.*

To meet the requirements of systematic sampling for the survey of vegetation, some device must be found by which the points may be located in the field at regular intervals, and in such a way that their actual location in practice cannot be influenced by the discretion of the operator. For this purpose it was considered that a simple spoked wheel that runs on its spoke ends, i.e. a wheel without a rim, would serve adequately if one of its spokes, of sufficiently small diameter (or sharpened to a point), were marked by a distinctive colour and used thus to locate the sampling points. The marked spoke would be equivalent to the pin of the point quadrat bridge, and the rest of the wheel would serve merely to convey the free point of the marked spoke to equidistant points in the field. Each revolution of the wheel would furnish thus a point record.

A miniature wheel of the type described, 1·8 inches (4·6 cm.) in diameter, similar to a tailor's wheel, was constructed and a series of laboratory trials was conducted with it.

---

* Similarly Madow and Madow (1944), Hansen and Hurwitz (1943), and others, have reported on the use of systematic samples; but no accepted theory, such as that for random samples, has apparently yet been established for two dimensional systematic sampling procedures.

LABORATORY EXPERIMENTS.

EXPERIMENT 1.

It must be mentioned here, since it does not appear to have been positively stated previously in the literature, that the point method of survey is based on a well-known theorem in the theory of probability, in which it is stated in effect that, if a given surface is partially or wholly occupied by discs or cards, of any shapes or sizes, without overlapping, the probability that a random point will lie within the perimeter of one of the discs or cards is equal to the total area of the discs or cards divided by the area of the said surface.* (Levy and Roth, 1936.)

Thus, if a large number of points is scattered over the surface, the number of points that fall within the perimeters of the discs or cards relative to the total number of points will furnish a direct estimate of the proportion of the surface covered by discs or cards, with an accuracy that is dependent upon the extent to which the surface is actually covered by discs or cards and the number of points employed.

In the experiment under review, a table top, 125 by 46 inches (317·49 × 116·84 cm.), or 5,750 square inches (37,095·4 sq. cm.), was partly covered by round, cardboard discs of three different sizes, punched from sheets of three different colours, so that within each size group there were equal numbers of discs of each of the three different colours. The numbers, sizes, and colours of the discs and the extent to which the table was covered by each size/colour group, were as follows:—

Discs.	*Large. Red, Brown, Black.*	*Medium. Red, Brown, Black.*	*Small. Red, Brown, Black.*
Size—			
sq. in.....	0·3068	0·2217	0·1725
(sq. cm.).....	(1·9793)	(1·4303)	(1·1129)
Number of each colour....	1,000	1,384	1,778
Percentage of table covered by each colour (calculated)	5·3	5·3	5·3

The discs were scattered on the table with no particular pattern or design, but care was taken that the discs should not overlap one another. They were distributed on the table in the following order successively:—

1. Large red alone.
2. Large red and large black.
3. Large red, black and brown.
4. Large red, black and brown, and medium red.
5. Large red, black and brown, and medium red and black.
6. Large red, black and brown, and medium red, black and brown.
7. Large red, black and brown, medium red, black and brown, and small red.
8. Large red, black and brown, medium red, black and brown, and small red and black.
9. All sizes and colours.

* The concept enunciated by Crocker and Tiver (1948), and Nielen and Dirven (1950), that the point method of survey is essentially a quadrat technique, in that a point can be considered a quadrat of minute area, invokes the principle of area samples, complicates the issue, and thereby destroys the particular advantage of the point concept, namely, its simple conformance with the basic principle of probability.

With each successive distribution of the discs on the table, the wheel, with one distinctive spoke, was rolled up and down (haphazard) over the surface of the table until 1,000 point records were obtained. Whenever the sharpened point of the marked spoke struck a disc at any point within, or on, its circumference, it was recorded as a " strike ". Otherwise it was recorded as a " miss ".

Initially, with the first distribution of the discs on the table (large red only), as the number of point records that would be required to furnish a reasonably accurate estimate of the cover was not known, trial sets of 100 points each were recorded separately. By inspection it was found that approximately 1,000 points were required to furnish an estimate that did not differ from the true value by more than about 1 per cent of cover.

Theoretically, if random samples are taken, the sizes and pattern of spread of the discs on the table should have no influence on the estimates; the total area of the discs on the table is the only criterion that should affect the result.

The results of the successive 1,000 point records are set out in Table 1, in which the number of strikes per 1,000 point samples required to reflect a percentage cover of 5·3 is 53, i.e. $\frac{53}{1{,}000} \times 100 = 5{\cdot}3\%$.

TABLE 1.—*Number of Strikes and Percentage Cover per* 1,000 *Points.*

Sample.	Size and Colour of Discs.									Total Cover (per cent).	
	Large.			Medium.			Small.				
	Red.	Black.	Brown.	Red.	Black.	Brown.	Red.	Black.	Brown.	Est.	Actual.
1.....	58	—	—	—	—	—	—	—	—	5·8	5·3
2.....	53	54	—	—	—	—	—	—	—	10·7	10·6
3.....	48	52	58	—	—	—	—	—	—	15·8	15·9
4.....	55	57	46	48	—	—	—	—	—	20·6	21·2
5.....	54	54	52	42	53	—	—	—	—	25·5	26·5
6.....	60	51	51	51	44	63	—	—	—	32·0	31·8
7.....	56	55	52	53	51	49	46	—	—	36·2	37·1
8.....	52	59	53	51	53	57	59	62	—	44·6	42·4
9.....	57	57	49	36	61	53	56	56	63	48·8	47·7

From the table it will be seen that the estimates obtained showed close agreement with the actual values of cover as calculated from the known areas of the discs.

Since the samples were large, the results were analysed as a normal distribution; but as the data were non-orthogonal, and the ordinary analysis of variance could not therefore be employed, constants were fitted instead, by the method of least squares. The only assumption made was that the class frequencies in the population were equal. The results of the analysis are summarised in Table 2.

TABLE 2.—*Analysis of Variance.*

Source of Variation.	Degrees of Freedom.	Sum of Squares.	Mean Square.	F.	Significance.
Total	44	1,308	—	—	—
Between Groups	8	494·16	61·77	2·732	S
Fitting Constants for Between Groups:—					
(*a*) Sizes	2	183·38	91·69	4·056	S
(*b*) Colours	2	139·24	69·62	3·080	N.S.
(*c*) Interactions	4	254·95	63·74	2·819	S
Error	36	813·84	22·61	—	—

S = Significant at P = 0·05.
N.S. = Not significant at P = 0·05.

From Table 2 it follows that the differences between the means in respect of different sizes of discs, and also the means for interaction, were significant, but that the differences between the means in respect of different colours of discs were not significant.* These results are obviously not in conformance with the true position, and closer examination showed that the values of variance of the sets of samples in respect of the different size groups were not homogeneous: these were as follows:—

Size of Disc.	*Degrees of Freedom.*	*Variance.*
Large	23	12·46
Medium	14	47·43
Small	5	37·60

Calculated (theoretical) variance (npq) obtained from the binomial distribution: 50·19.

The variance in respect of the large discs is significantly smaller than that in respect of both the medium and the small discs; but the difference between the values of the last two is not significant, both of which are consistent with the calculated, theoretical value. The differences in variance in respect of the different colours of discs within any size group are not significant. These findings readily account for the results obtained from the analysis of variance previously mentioned. The explanation of the non-homogeneity of the values of variance in respect of the different sizes of discs will become apparent later in this section of the paper.

To test further the method of survey by means of systematic points, the following series of laboratory tests was conducted.

* As the differences between the estimates in respect of the different sizes of discs showed a significance which could not possibly have existed in terms of the experimental set-up, the results indicated therefore an error of sampling technique. Similarly, there could not possibly have been any real interaction between sizes and colours, and this test was therefore made in a search for further anomalies in technique.

EXPERIMENT 2.

The object of the tests was to determine—

(1) whether the distribution of the sampling means or totals obtained from a number of systematic points, arranged in different ways, would conform to the binomial distribution equally as well as those obtained from a similar number of random points;
(2) whether the average size of the individual units (discs, cards or vegetation), and/or the spread of the sampling points in relation thereto, would affect the results in any way;
(3) whether different patterns of spread of the "vegetation", and/or the spread of the sampling points in relation thereto, would affect the results in any way.

A rectangle, 27·5 by 65 inches (69·85 × 165·10 cm.), with an area thus of 1,787·5 square inches (11,531·82 sq. cm.), was described on a sheet of white cartridge paper and fixed to a table top. Cards of stiff, black paper, of various known areas, were placed successively in the rectangle, and the percentage area of the rectangle covered by the cards was therefore accurately known. A rectangular frame, 66 by 29 inches (167·64 × 73·66 cm.), inside measurements, was constructed, and thin harness threads, 0·25 inches (0·635 cm.) apart, were strung across it at right angles to one another, to form a grid of small squares of 0·25 inches (0·635 cm.) side. Thus when the frame (grid) was placed over the rectangle on the table, the rectangle was divided into 28,600 squares, and included thus 28,231 points of intersection of the threads of the grid. These points of intersection served, in the subsequent tests, as the sampling points from which further samples could be drawn either at random, or in any other manner required.

Test 1.

To examine the suitability of the sampling method for determining the percentages of the rectangle covered by the cards, or their collective pieces, the following tests were made, in which, to ensure a rigorous test, small values of p, $\left(\frac{\text{total area of cards or pieces}}{\text{area of rectangle}}\right)$, i.e. small percentages of cover, were used.

The sizes of the cards used in the test, the percentage of the rectangle covered by each card, and the values of probability were as follows:—

Card.	*Size in inches.* (*sq. cm.*)	*Cover, per cent.*	*Value of p.*
1.....	5 × 4 (129·03)	1·119	0·01119
2.....	5 × 8 (258·05)	2·238	0·02238
3.....	6 × 10 (387·08)	3·357	0·03357
4.....	8 × 10 (516·11)	4·476	0·04476
5.....	10 × 10 (645·14)	5·594	0·05594

Each whole card was placed in turn in the rectangle on the table, the grid fitted in position, and the data in respect of strikes or misses of all the 28,231 points (i.e. the maximum possible distribution of points with the particular grid) were recorded separately. Each card was then punched into a large number of small irregular pieces of different shapes and sizes, similar to confetti, with a maximum diagonal length of 0·25 inches (0·635 cm.). The total area of the

pieces was obviously equal to the area of the card. The pieces from each card were strewn in turn in the rectangle on the table. They were spread first as uniformly as possible, and then closely placed in a narrow diagonal strip, so that the greater surface of the rectangle was devoid of all pieces. Special care was taken that no pieces should overlap. In one instance the pieces were closely placed in three small areas, in the form of two circles and a diamond, so that again the greater surface of the rectangle was devoid of any pieces. This is subsequently referred to as the pattern arrangement. In each of these cases also, the data of all the 28,231 points were recorded separately.

The results of all these tests are summarised in Table 3.

TABLE 3.

Card.	Condition.	Strikes.	Derived p.	Actual p.
1...	Whole card.....	320	0·01134	0·01119
	Pieces evenly spread.....	334	0·01183	0·01119
	Pieces arranged in diagonal strip....	312	0·01105	0·01119
2...	Whole card.....	628	0·02225	0·02238
	Pieces evenly spread.....	753	0·02667	0·02238
	Pieces evenly spread.....	667	0·02363	0·02238
	Pieces arranged in diagonal strip....	667	0·02363	0·02238
3...	Whole card.....	873	0·03092	0·03357
	Pieces evenly spread.....	979	0·03468	0·03357
	Pieces arranged in diagonal strip....	909	0·03220	0·03357
4...	Whole card.....	1,225	0·04339	0·04476
	Pieces evenly spread.....	1,292	0·04577	0·04476
	Pieces arranged in pattern.....	1,192	0·04222	0·04476
5...	Whole card.....	1,605	0·05685	0·05594
	Pieces evenly spread.....	1,643	0·05820	0·05594
	Pieces arranged in diagonal strip....	1,692	0·05993	0·05594

From the table it is seen that the estimates obtained from the sampling method were in close agreement with the actual, known, values.

TEST 2.

To compare the agreement of the distribution of totals of systematic samples (arranged in straight lines), relative to that of random samples, with the binomial distribution, the following tests were made:—

1. The data of 100 sets of 200 random points each were read off from the results of card 4 of Test 1 in respect of both the even spread and the pattern arrangement of the pieces.

2. Using again the data of card 4 of Test 1 in respect of the two arrangements mentioned, 100 sets of 200 points each were located in the following way:—

By taking lines parallel to the shorter axis of the grid, spaced 35 units apart, and points within the lines spaced 4 units apart, an average sample of 200 points, i.e. an average of 8 lines with an average of 25 points each, was obtained. This was repeated 100 times. The starting point was found each time by taking a pair of random numbers for the X and Y axes within the square 0 to 20 units on both axes of the grid.

The results of the tests, together with those of a binomial distribution, with p = experimental mean, are summarised in Tables 4 and 5.

TABLE 4.—*Data from Random Points.*

Number of Strikes.	Experimental Frequencies.		Expected Frequencies.	
	Even Spread.	Pattern Arrangement.	Even Spread.	Pattern Arrangement.
0	0	0	0	0
1	0	0	0	0
2	0	0	1	1
3	4	3	2	3
4	5	8	5	6
5	9	11	8	9
6	7	10	12	12
7	13	10	14	14
8	12	21	14	14
9	18	12	13	13
10	14	7	11	10
11	11	6	8	7
12	2	6	5	5
13	3	2	3	3
14	2	3	2	2
15	0	1	1	1
16	0	0	1	0

Even spread: $p = 0{\cdot}041$.
Pattern Arrangements: $p = 0{\cdot}040$.

TABLE 5.—*Data from Systematic Points.*

Number of Strikes.	Experimental Frequencies.		Expected Frequencies.	
	Even Spread.	Pattern Arrangement.	Even Spread.	Pattern Arrangement.
0	0	0	0	0
1	0	0	0	0
2	0	0	1	1
3	3	0	1	2
4	4	3	3	4
5	6	11	6	7
6	9	13	9	10
7	14	6	12	12
8	11	23	13	14
9	10	13	14	13
10	10	8	12	12
11	14	9	10	9
12	8	4	7	7
13	6	2	5	4
14	4	3	3	3
15	1	2	2	1
16	0	1	1	1
17	0	1	1	0
18	0	1	0	0

Even spread: $p = 0{\cdot}045$.
Pattern Arrangement: $p = 0{\cdot}044$.

From the random samples the χ^2 values $0{\cdot}5>P>0{\cdot}3$ are derived in respect of the evenly spread pieces, and $0{\cdot}7>P>0{\cdot}5$ in respect of the pattern arrangement; and from the systematic samples, $0{\cdot}9>P>0{\cdot}8$ in respect of the evenly spread pieces, and $0{\cdot}2>P>0{\cdot}1$ in respect of the pattern arrangement. The results of both methods of sampling are therefore consistent with those of a binomial distribution, in respect of both the evenly spread pieces and the pattern arrangement, and indicate therefore that the systematic method of sampling will remain valid for any manner in which the pieces (vegetation) may be grouped or spread over the surface provided there is no regular periodicity in their distribution corresponding with that of the sampling points. The results of the tests are regarded as very satisfactory since the values of both n and p selected were small.

In the field, the condition mentioned may possibly (theoretically at least) be encountered: the plants (or some of them) may be grouped in some systematic manner, having a periodicity equal to, or some function of, the distance between successive sampling points located systematically in straight lines. This condition could be satisfied for example by a row crop; alternatively a simultaneous periodicity in all directions might conceivably exist, as for example the concentric rings of ripples formed by a handful of pebbles cast into a still pool of water. The existence of such a condition in vegetation, however, seems unlikely; and the evidence furnished by the investigations of Archibald (1948), and others, indicates that, although the individuals of a species or population may be aggregated in clusters, the centres of such clusters tend to be distributed at random.

Test 3.

To examine the effects of the size and spread of the units of cover, in relation to the spread of the sampling points, on the variance of the sample means, the following tests were made:—

Numbers of points, 1,664 and 1,872 respectively, were located in lines in such a way that (*a*) the distance of the points within the lines was equal to that between the lines, and (*b*) the distance of the points within the lines was considerably less than that between the lines:—

(*a*) Ten samples, with an average of 1,664 points each, were taken according to the 4 × 4 pattern of sampling; i.e., by taking the points where every fourth thread in the X and Y directions of the grid intersected. The starting points were determined by taking ten random points within the square 0 to 10 units on both the X and Y axes of the grid.

(*b*) Ten samples, with an average of 1,872 points each, were taken, with points spaced 2 units apart within the lines, and 7 units between lines. The starting points were located as for (*a*) above.

The original data of Test 1 were used for the purpose and the results are summarised in Tables 6 and 7.

TABLE 6.—*Data from* 1,664 *Points Equally Spaced Within and Between Lines.*

Card No.	Means.			
	Whole Card.	Diagonal Strip.	Even Spread.	Binomial Value.
1.....	0·01178	0·01148	0·01190	0·01119
2.....	0·02338	0·02458	0·02608 (1) 0·02404 (2)	0·02238
3.....	0·03395	0·03185	0·03618	0·03357
4.....	0·04760	0·04453 (P)	0·04609	0·04476
5.....	0·05974	0·06382	0·05751	0·05594

Card No.	Standard Deviations.			
	Whole Card.	Diagonal Strip.	Even Spread.	Binomial Value.
1.....	0·00051	0·00215	0·00259	0·00258
2.....	0·00066	0·00386	0·00275 (1) 0·00283 (2)	0·00363
3.....	0·00274	0·00473	0·00547	0·00442
4.....	0·00062	0·00373 (P)	0·00466	0·00507
5.....	0·00130	0·00504	0·00463	0·00563

(P) denotes pattern arrangement.
(1), (2): duplicate samples (see Table 3).

TABLE 7.—*Data from* 1,872 *Points Spaced Two by Seven Units Apart.*

Card No.	Means.			
	Whole Card.	Diagonal Strip.	Even Spread.	Binomial Value.
1.....	0·01191	0·01143	0·01223	0·01119
2.....	0·02372	0·02468	0·02628 (1) 0·02537 (2)	0·02238
3.....	0·03510	0·03424	0·03734	0·03357
4.....	0·04898	0·04487 (P)	0·04370	0·04476
5.....	0·06159	0·06229	0·05572	0·05594

Card No.	Standard Deviations.			
	Whole Card.	Diagonal Strip.	Even Spread.	Binomial Value.
1.....	0·00026	0·00171	0·00370	0·00243
2.....	0·00052	0·00285	0·00570 (1) 0·00657 (2)	0·00342
3.....	0·00101	0·00604	0·00373	0·00416
4.....	0·00071	0·00660 (P)	0·00580	0·00478
5.....	0·00084	0·00859	0·01073	0·00531

(P), (1) and (2), as in Table 6.

From the tables it is seen that the means obtained from the two different methods of sampling were both in close agreement with the true values and were equally reliable irrespective of the manner in which the surface was covered by the cards or their pieces. In respect of the standard deviation however, the estimates furnished for the whole cards were low, while there appeared to be a slight tendency to over-estimate the standard deviation in respect of the different arrangements of the pieces when the sampling lines were spaced further apart, and a smaller tendency to under-estimate it with the 4×4 spread of the sampling points. This aspect was investigated further in the following experiment.

EXPERIMENT 3.

A rectangle, 124 by 45 inches (314·95 × 114·30 cm.), was set out on a laboratory bench, and a card, 18 inches (45·72 cm.) by 18 inches, was placed within the rectangle. The percentage of the area of the rectangle covered by the card was thus 5·806. Nine lines, spaced 5 inches (12·70 cm.) apart, parallel to the long axis of the rectangle, were set out in it, in such a way that the first line coincided with the left hand long boundary of the rectangle. Twenty-three points, 5·5 inches (13·97 cm.) apart, were located along each line by means of the miniature wheel described in the first experiment. In this way 207 sampling points were obtained, and the strikes registered on the card were recorded. The set of lines was then moved 0·5 inches (1·27 cm.) to the right, and the operation repeated. This procedure was repeated ten times in all to furnish ten separate sets of 207 sampling points each. The card was then subdivided successively into 4, 16, 64, 256, 1,024, 4,096 and 16,384 squares of equal size. After each successive subdivision, the square pieces were scattered haphazard within the rectangle; but no piece was allowed to overlap another. Ten separate samples of 207 points each were taken in respect of each successive subdivision of the card, in the same way as that described for the whole card. The percentage of the area of the rectangle covered in all cases was 5·806.

The results of the test are set out in Table 8.

TABLE 8.

Successive Sets of 10 Samples each (2,070 points).	Size of pieces (side of square).	Mean Strikes per 207 Points.	Cover (per cent).	Experimental Variance.	Experimental Standard Deviation.
1.....	18″ (Whole Card)	11·8	5·70	0·62	0·79
2.....	9″ (22·86 cm.)	12·9	6·23	2·32	1·52
3.....	$4\frac{1}{2}$″ (11·43 cm.)	11·7	5·65	3·57	1·89
4.....	$2\frac{1}{2}$″ (5·715 cm.)	9·4	4·54	6·49	2·55
5.....	$1\frac{1}{8}$″ (2·858 cm.)	11·1	5·36	6·77	2·60
6.....	$\frac{9}{16}$″ (1·427 cm.)	11·7	5·65	5·57	2·36
7.....	$\frac{9}{32}$″ (0·715 cm.)	12·2	5·89	13·29	3·65
8.....	$\frac{9}{64}$″ (0·358 cm.)	11·3	5·46	17·57	4·19

True cover, per cent..... 5·81
Theoretical variance..... 11·32
Theoretical standard deviation..... 3·36

From the table it will be seen that the estimates of cover were again in close approximation to the true value; that the values of variance of the successive sets of samples increased as the size of the pieces diminished; but that the values remained consistently lower than the theoretical value even after the side of the pieces had decreased to considerably less than the distance between consecutive sampling points in the lines; and that the theoretical value was exceeded (albeit not significantly) in the last two sets of samples only. These results are contrary to what was initially expected, namely that, as soon as the cross sectional length of the pieces became less than the distance between the points, the variance of separate samples would tend to the theoretical value. The results of the test may be explained by the fact that, while the distance between points in the sampling lines remained constant at 5·5 inches (13·97 cm.) and the distance between the lines in any sample was 5 inches (12·70 cm.), the distance between the corresponding lines of each set of samples was only 0·5 inches (1·27 cm.), since the lines were moved that distance to the right for each successive sample. Only after the fifth subdivision of the card therefore [size of pieces $\frac{9}{16}''$ (1·43 cm.) side] did the distance between the lines of successive samples exceed the cross sectional length of the card.

If this is the true explanation, then, were the set of ten samples to be considered first in two groups formed by taking in each case the values of alternate repetitions, and were the variance between the two groups then to be eliminated, reducing thus the degrees of freedom, for estimating the residual variance of all the data, to 8, the " within group " variance should afford a better approximation to the theoretical variance since this procedure would be equivalent in effect to an increase to 1 inch (2·54 cm.) between corresponding lines of a set of samples. The calculations so made, yield the following values of variance for the sets 1 to 8 respectively: 0·70, 2·50, 4·00, 7·25, 7·50, 5·95, 14·50 and 17·65. These values show an increase in all cases, in which the maximum possible increase is necessarily limited to $\frac{1}{8}$ of the original value. If the samples in each set of 10 are considered in three groups of 4, 3 and 3 per group, and the distance between the corresponding lines of a set of samples is thereby increased in effect to 1·5 inches (3·81 cm.), and the degrees of freedom for estimating the variance is thus reduced to 7, the values of variance for the sets 1 to 8 become 0·71, 2·59, 4·53, 8·10, 8·20, 4·77, 12·77 and 20·20, respectively. Since, however, the available data were insufficient to permit of further extensions in effect of the distance between the corresponding lines of successive samples, and in any case close conformance with the theoretical values of variance could not be expected from this procedure as the values of the original set of data remain inherently related, the following experiment was performed.

EXPERIMENT 4.

A rectangle, 27 by 13·25 inches (68·58 × 33·65 cm.), was set out on a laboratory bench and the surface variously covered by square cards, as shown in the following schedule:—

Serial No.	No. of Cards.	Side of a Single Card.		Percentage Cover.
		in.	cm.	
1	1	5·6	14·22	8·77
2	4	2·8	7·11	8·77
3	16	1·4	3·56	8·77
4	16	1·25	3·17	7·00
5	16	1·00	2·54	4·45
6	64	0·7	1·78	8·77
7	256	0·35	0·89	8·77
8	1,024	0·175	0·44	8·77

Ten lines, spaced 1·4 inches (3·56 cm.) apart, parallel to the long axis of the rectangle, were set out in it in such a way that the first line coincided with one long boundary of the rectangle. With the use of the small wheel already described, of which two pairs of opposite spokes were distinctively marked, 20 points, 1·38 inches (3·51 cm.) apart, were located along each line, and the strikes registered on the cards were recorded. After a sample of 200 points had been obtained in this way, the card, or set of cards, was rearranged haphazard in the rectangle, and a second sample of 200 points was taken along the same set of 10 parallel lines whose positions remained fixed throughout the experiment. In this way ten independent samples of 200 points each were obtained in respect of each set of cards reflected in the foregoing schedule.

The results of the experiment are summarised in Table 9; and in Figure 1 the ratio, experimental S.D./expected S.D., is plotted against the ratio, distance between points/diagonal length of cards.

TABLE 9.

Serial No.	Experimental mean of 10 Samples.		Expected Values.		Experimental Values.		Expected Values (Binomial).		Ratio of Experimental to Expected Variance.
	Strikes.	Cover. %	Strikes.	Cover. %	Variance.	S.D.	Variance.	S.D.	
1.....	16·5	8·25	17·5	8·77	0·72	0·85	16·00	4·00	0·045
2.....	17·1	8·55	17·5	8·77	1·66	1·29	16·00	4·00	0·104
3.....	17·0	8·50	17·5	8·77	2·44	1·56	16·00	4·00	0·153
4.....	12·6	6·30	14·0	7·00	2·49	1·58	13·00	3·61	0·192
5.....	7·9	3·95	8·9	4·45	8·32	2·88	8·54	2·92	0·974
6.....	18·9	9·45	17·5	8·77	12·99	3·60	16·00	4·00	0·812
7.....	18·0	9·00	17·5	8·77	20·89	4·57	16·00	4·00	1·306
8.....	18·4	9·20	17·5	8·77	15·38	3·92	16·00	4·00	0·961

From the results of the experiment it is seen that—

(1) when the diagonals of the cards were greater than the distance between sampling points, i.e. within or between the sampling lines, the values of variance of the respective groups of samples were considerably lower than the theoretical values calculated for random samples;

(2) as soon as the diagonals of the cards became equal to, or smaller than, the distance between sampling points, the values of variance tended to the theoretical values, and the sampling points became therefore independent;

(3) although the values of variance in respect of the larger cards were lower than those in respect of the smaller cards, the estimates of the sample means were in truth no more accurate when the cards were large.

The statement by Yates (1949), that systematic sampling yields an unbiassed estimate of the mean, but that the estimate of the standard deviation is smaller than that of random sample means, is not wholly endorsed by the results of the experiment, in that the standard deviations in respect of the smaller cards in the experiment conform to those of the binomial distribution. The underestimation of the standard deviation in respect of the larger cards, however, explains the seeming accuracy of the point-quadrat method reported by

Croeker and Tiver (1948). In the conventional point quadrat bridge, or frame, the points are located so close to one another relative to the diameters of most of the plants that the observations are not independent, as confirmed by the work of Corby (1950) to which reference has previously been made; and the variance is consequently under-estimated.

In terms of the results of the last two experiments those of the first laboratory experiment become readily explicable.

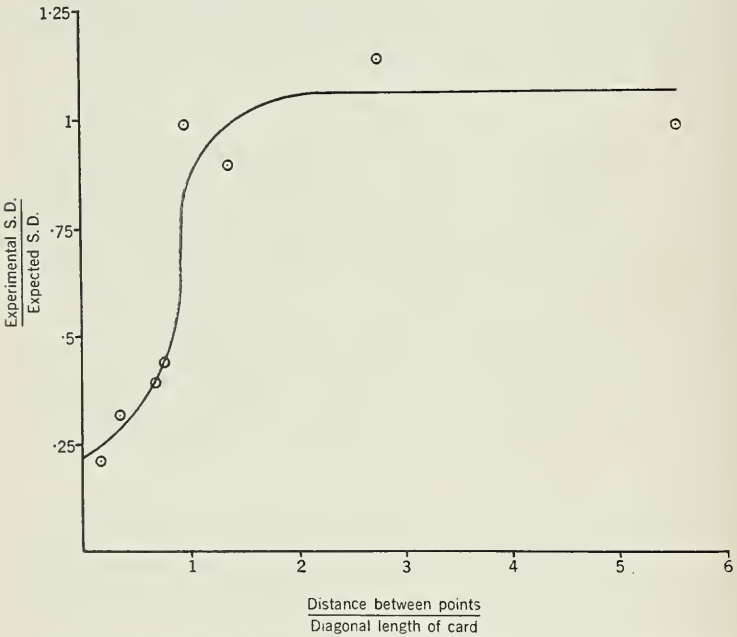

FIG. 1.—Graph showing the relationship between the sizes of the cards relative to the distance between sampling points and the experimental standard deviation expressed as a fraction of the expected value.

From the results of all these experiments it is concluded that systematic samples of points in straight lines yield unbiassed means and estimates of standard deviation that approximate those of the binomial distribution, irrespective of the pattern of the population, provided the distance between the points within and between sampling lines is greater than the cross-sectional lengths of the individuals, or contiguous clusters of individuals, comprising the population to be sampled. To this must be added, however, a second requisite, namely that, when a defined area (field or paddock) is to be sampled, the area must be adequately covered by the spread of the sampling points, since it will be obvious that if the points were all to be grouped in, say, one third of the area, or the required number of points were to be obtained from a single line through the area, the estimates derived from the samples could hardly be

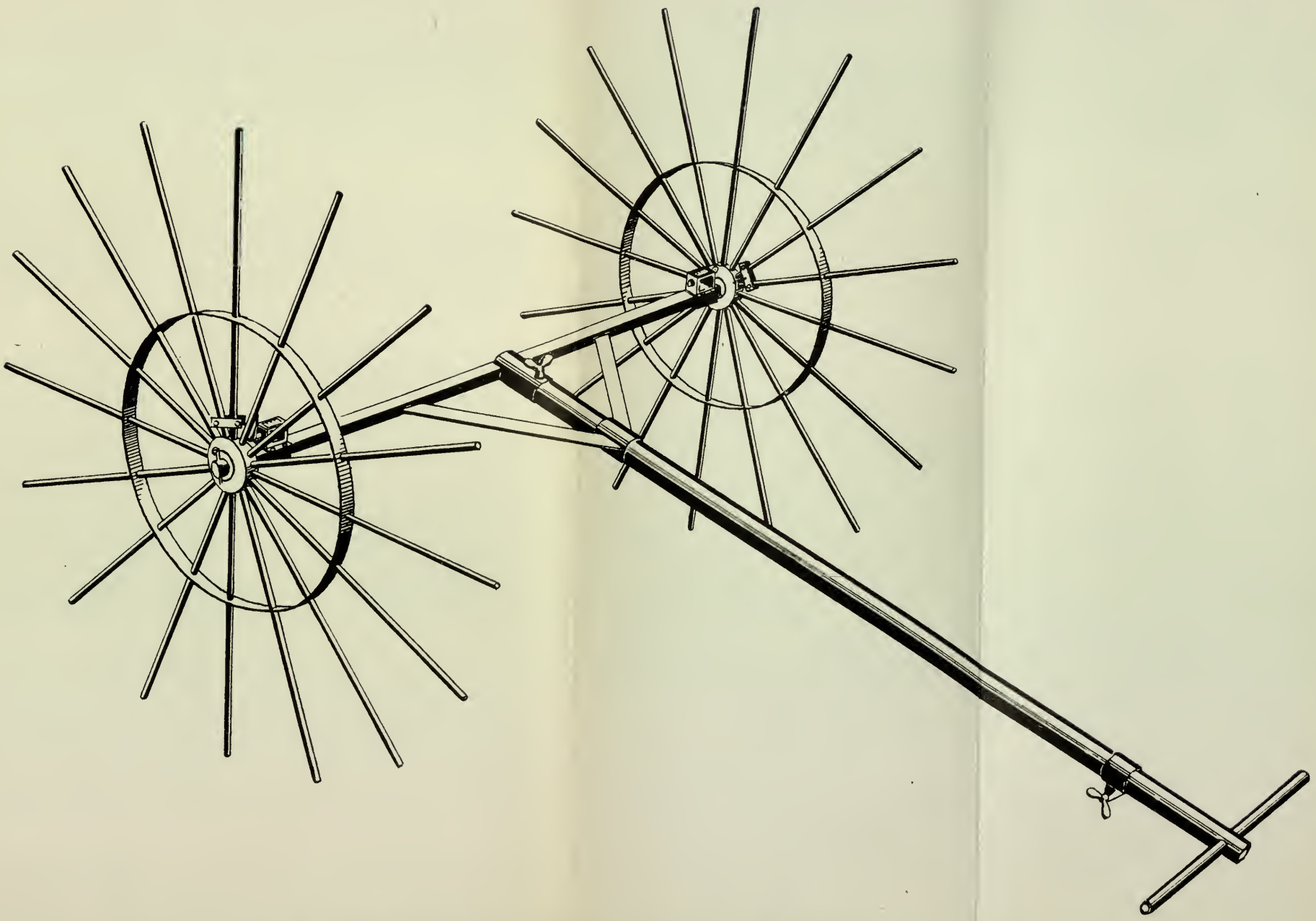

FIG. 2.—Sketch of the wheel apparatus used in the field.
Dimensions: Axle length, 3·54 ft. (1·08 m.); Extensible (telescopic) shaft, 7 ft. (2·13 m.) when fully extended.
Diameter of wheels, 3 ft. (0·91 m.). Projection of spokes beyond reinforcing band, 10 in. (25·4 cm.). Diameter of spoke, 0·3 in. (0·76 cm.).
Each wheel is provided with a counter attached to the axle. The wheels, axle, and shaft are all readily detachable to facilitate transport of the apparatus.

expected to furnish an accurate reflection of the true condition of the whole area; unless it were exceptionally uniformly occupied by the population, or, in the second case, the line of points just happened to coincide with the population mean, i.e. the mean density and composition of the population in the area.

The aspect of adequate coverage by sampling points, and their requisite number, will be dealt with when the data obtained in the field are presented.

FIELD EXPERIMENTS.

It was concluded from the laboratory experiments that a wheel with a distinctive spoke was a suitable device for the location of any requisite number of systematic sampling points. It remained then to devise a wheel that would be suitable for use in the field, in the type of vegetation to which it was desired to apply the method of survey, and to test the reliability of the method under field conditions.

THE VEGETATION.

The type of vegetation in which the tests, subsequently described in this paper, were conducted, is variously known in South Africa as mixed Karoo, false Karoo, or " gebrokeveld " (broken veld). It occupies a large tract of country, approximately 30,000 square miles (77,700 sq. Km.), in which Middelburg, C.P., with a mean annual rainfall of approximately 13 inches (33 cm.), is more or less centrally situated.

The vegetation is composed of a mixture of a large number of species including numerous relatively short tussock grasses, a few low growing, creeping grasses, and a large number of species of small desert shrubs, as well as various forbs, annual herbs and grasses. The vegetation is sparse and open. The plants exhibit a variety of growth forms, and range in height from less than 1 inch (2·54 cm.) to about 3 feet (0·91 m.). The great majority of the plants, however, are usually less than 18 inches (45·7 cm.) tall, and the soil cover ranges from about 5 to 20 per cent (Plate 1).

THE WHEEL APPARATUS.

The wheel required for the field surveys must be sufficiently large and heavy to enable the spokes to penetrate through the plants freely to the soil surface, without riding on the stiffer shrubs, and to ensure also that the sampling points will be sufficiently widely spaced, in conformance to the requirement previously stated in Laboratory Experiment 4. For the particular vegetation type, therefore, a wheel of radius at least 18 inches (45·7 cm.) was necessary; but as it was thought that such a wheel would be too heavy and cumbersome to manipulate with comfort in the field, the apparatus shown in Fig. 2 was constructed.

In order to minimise any errors that may arise on the score that it is not physically possible to construct a theoretical point, it is essential that the diameter of the spoke used for determining the strikes (or at least that of its lower end) should be reduced to the smallest dimension consistent with its practical use in the field. Further, to ensure that the results of all surveys that are to be compared are indeed comparable, the same diameter of spoke end should be employed throughout; this diameter should be recorded against each survey to ensure that, in subsequent surveys, the same diameter of spoke is employed. (The influence of differences in diameter of spoke ont he results of surveys, and on their statistical interpretation, is at present being investigated.)

To ensure maximum speed, when one marked spoke of one wheel only is employed, a team of three persons is required for the survey: one to draw the apparatus, one to observe the strikes and identify the species struck, and one to record the strikes. Of this personnel it will be obvious that one only need be trained sufficiently to identify the species at a glance, one need be no more than literate, and the third need possess no qualifications other than the power of traction under direction. If, however, time is of less consequence than the number of personnel employed, the observer may record his observations himself.* If required, the distance between sampling points may be reduced by employing more than one marked spoke in the wheel, without necessitating any increase in personnel.

If both wheels are employed in the survey, as is convenient when small areas are to be sampled, one additional observer is required; and if more than one spoke is employed in each wheel, the survey is considerably expedited. When relatively large areas have to be surveyed, however, this practice is usually not admissible, as the area would be inadequately covered by the spread of the requisite number of sampling points, as discussed in Laboratory Experiment 4, and dealt with more fully subsequently in this section.

Since it is convenient to record only the strikes, and to neglect thus the misses, the counters fitted to the apparatus are used to record the total number of sampling points, i.e. revolutions of the wheel. The observations are continued, thus, until the counter, which is set at zero at the start of each operation, indicates that the requisite number of sampling points has been located.

DEFINITION OF A STRIKE.

Since, in the field, some latitude of interpretation exists, and the question of whether a strike has been scored or not is therefore by no means as readily decided as in the laboratory, it is essential that some definition should be formulated in regard thereto, and thereafter strictly applied.

As mentioned earlier in this paper, it was decided to adopt the criterion of basal cover as a measure of the vegetation, and the definitions illustrated in Figures 3 and 4 were consequently formulated and applied in the tests that follow.

The significance of the distinction drawn in Figure 3, between examples 5 and 6, on the one hand, and example 7, on the other, will be readily appreciated when it is considered that, should both plants be edible to grazing animals, and were example 5 to be regarded as a strike, differences in relative values in respect of these two plants would be obtained from the surveys depending upon whether the vegetation of the particular area surveyed happened to be grazed at the time or not. Example 2 of Figure 4 represents a condition occasionally encountered in mixed Karoo vegetation. The dwarf shrubs, usually regarded as single plants, are in truth, when mature, aggregates of individuals in which each woody stem arising from the soil surface is a separately rooted individual. When these individuals are closely grouped, and no other plants occur within the cluster (Fig. 4, example 1), to facilitate the survey, the cluster is regarded as an individual; and when the spoke strikes within its rooted perimeter therefore, it is recorded as a strike on the particular species, even though the spoke may not actually touch a stem of the shrub at ground level. When however the

* To dispense with the services of a recorder, without sacrificing speed, it may be practicable to attach to the apparatus, or to the observer, a simple form of dictaphone, at a relatively low cost.

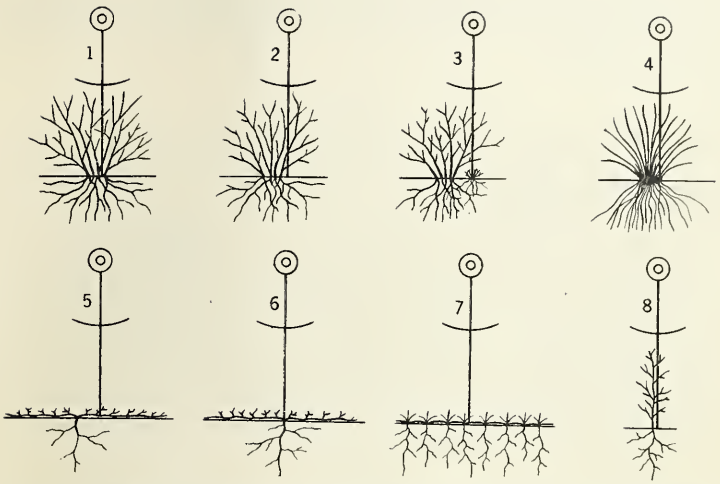

FIG. 3.—Diagrammatic sketches showing positions of the spoke in strikes and misses. 1. Strike. 2. Miss. 3. Small plant struck. 4. Strike. 5. Miss. 6. Strike. 7. Strike. 8. Miss.

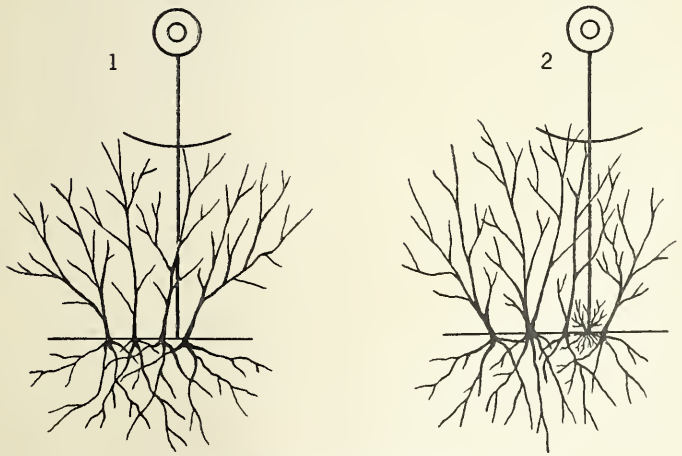

FIG. 4.—Diagrammatic sketch showing two strikes. 1. Strike on shrub. 2. Strike on small plant.

cluster becomes sufficiently open to permit the growth of other plants within it, as in example 2 of the figure, the shrub is considered to have broken up into two or more separate " individuals ", and a strike on the small plant is accordingly recorded.

EXPERIMENT I.

To see whether the results obtained with the use of a miniature wheel in the laboratory would be returned by similar tests in the field, the following experiment was performed:—

In a stand of mixed Karoo vegetation, a rectangle, 132 by 126 yards (120·7 × 115·2 m.), was pegged out and 44 lines, 9 feet (2·74 m.) apart, parallel to the shorter side of the rectangle, were set out in it in such a way that the first line coincided with the left hand boundary of the rectangle. Forty-one points, 9·42 feet (2·87 m.) apart, were located along each line by means of the field apparatus of Figure 2; one marked spoke of one wheel of the apparatus was used, and the sampling lines were set out by means of flags so that the wheel could be drawn in straight lines from flag to flag. In this way a sample of 1,804 points was obtained, and the strikes registered according to the definition given were recorded.

Since, obviously, it was not possible to rearrange the vegetation each time before taking another sample (as was done in Lab. Expt. 4), subsequent samples were obtained by moving the set of sampling lines 0·9 feet (27·4 cm.) to the right for each successive sample in the same way as in Laboratory Experiment 3. In all, ten samples, with five different observers, were taken.

The results of the ten samples are set out in Table 10.

TABLE 10.—*Numbers of Strikes in Ten Samples of* 1,804 *Points Each, Obtained by Five Different Observers.*

Observers.	1.		2.		3.		4.		5.		TOTAL.
Samples.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
Species.											
Aptosimum depressum	5	—	4	2	2	1	—	2	2	2	20
Aristida spp.	15	16	18	26	28	25	20	22	22	24	216
A. vestita	8	9	8	6	6	10	6	5	3	2	63
Aster muricatus	5	2	1	—	—	1	—	—	1	1	11
Blepharis villosa	—	—	1	—	—	—	—	—	—	—	1
Berkheya rigida	—	—	1	1	—	—	—	1	—	—	3
Bulbostylis humilis	1	—	—	—	—	—	—	—	—	—	1
Chrysocoma tenuifolia	4	8	8	12	8	8	6	6	7	10	77
Crassula sp.	3	2	4	3	3	1	6	7	3	2	34
Cynodon incompletus	14	1	2	—	—	—	—	1	1	—	19
Eberlanzia spinosa	3	3	2	5	1	3	2	2	2	5	28
Euphorbia prostrata	—	—	1	—	—	—	—	—	—	—	1
Enneapogon brachystachyus	—	—	1	1	—	—	1	1	—	—	4
Eragrostis bergiana	—	—	—	—	—	—	—	—	1	1	2
E. lehmanniana	9	10	4	9	7	4	10	11	8	10	82
E. obtusa	—	—	2	—	—	1	—	1	—	—	4
Eriocephalus glaber	10	8	22	11	12	13	15	10	13	9	123
E. spinescens	2	—	—	2	2	—	1	—	—	—	7
Gazania jurineifolia	—	—	1	—	—	—	—	—	—	—	1
Geigeria passerinoides	—	—	1	—	—	—	—	—	—	—	1
Gnaphalium sp.	—	—	1	—	—	—	—	—	—	—	1
Helichrysum dregeanum	11	18	11	12	17	15	9	9	11	14	127
H. lucilioides	—	—	1	—	1	1	1	—	—	—	4
Hermannia coccocarpa	1	—	1	—	—	—	—	—	—	—	2
Indigofera alternans	1	—	—	—	—	—	—	—	—	1	2
Ifloga paronychioides	28	28	20	22	36	31	27	38	42	36	308
Lepidium sp.	—	1	—	—	—	—	—	—	1	—	2
Lycium arenicolum	7	9	5	6	5	8	7	7	4	7	65
Medicago aschersoniana	—	1	1	—	—	—	—	—	—	—	2
Mollugo cerviana	—	1	2	—	—	—	1	—	—	—	4
Nenax microphylla	1	2	—	1	1	1	1	—	—	—	7
Nestlera humilis	5	1	8	5	3	5	5	4	3	2	41
Osteospermum leptolobum	—	—	—	1	—	—	—	1	—	—	2
Oxalis depressa	3	4	6	4	3	5	3	2	4	4	38
Pentzia incana	26	23	21	15	18	29	19	22	22	14	209
Plinthus karrooicus	4	2	—	—	2	2	—	1	1	—	12
Phymaspermum parvifolium	14	16	15	21	13	16	15	14	22	18	164
Pteronia glauca	1	1	—	1	1	—	—	—	2	1	7
Pterothrix spinescens	—	—	—	1	—	—	—	—	—	—	1
Salvia clandestina	—	—	—	—	2	—	—	—	—	2	4
Schismus fasciculatus	10	15	15	8	17	21	20	17	13	12	148
Senecio burchellii	—	1	—	—	—	—	—	—	—	—	1
Sporobolus ludwigii	2	2	1	—	2	2	2	—	1	1	13
Tragus koelerioides	—	14	7	11	11	2	8	7	8	4	72
T. racemosus	5	2	3	5	8	3	7	4	3	6	46
Trichodiadema pomeridianum	—	—	—	—	—	—	—	1	—	1	2
Ursinia annua	—	—	—	—	—	—	—	—	1	1	2
Walafrida saxatilis	4	1	—	1	—	—	1	—	—	1	8
Wahlenbergia sp.	—	—	1	4	1	1	—	—	2	2	11
TOTAL	202	201	200	196	210	209	193	196	203	193	2,003
Cover per cent	11·20	11·14	11·09	10·86	11·64	11·59	10·70	10·86	11·25	10·70	11·10

The standard deviation of the ten samples, in respect of the total number of strikes (on all plants), and the strikes on eight different species, compared with the values calculated for a binomial distribution, with p = experimental mean, are given in Table 11. (In this table only those species with a mean of eight or more strikes per sample are reflected.)

TABLE 11.

Species.	Standard Deviation of Strikes calculated from the Data.	Standard Deviation of Strikes calculated from the point Binomial.
All plants	6·00	13·35
Aristida spp	4·33	4·52
Eragrostis lehmanniana	2·49	2·86
Eriocephalus glaber	4·00	3·49
Helichrysum dregeanum	3·16	3·55
Ifloga paronychioides	7·11	5·50
Pentzia incana	4·63	4·55
Phymaspermum parvifolium	3·03	4·03
Schismus fasciculatus	4·16	3·83

In Table 11 it will be seen that the value of the standard deviation in respect of the total number of strikes (all plants) is significantly lower than that of the calculated binomial value. This is readily explained by the fact that the vegetation showed a marked tendency to aggregation in clusters, of which the mean cross sectional length was observed to be greater than the distance through which the sampling lines were moved [0·9 ft. (27·4 cm.)] for each successive sample. In this respect the results are in conformance with those obtained in the laboratory.

With regard to the eight different species of Table 11, it is seen that the values of standard deviation conform to those of the binomial distribution and accord with what might have been expected: whereas the mean cross sectional length of the clusters was greater than 0·9 feet (27·4 cm.), and was responsible thus for an underestimate of the standard deviation, these clusters were composed of aggregates of different species of plants (more or less independently distributed over the area) whose mean diameters were less than 0·9 feet (27·4 cm.), and furnished thus the binomial values of standard deviation.

Finally, it will be seen by comparison of Tables 10 and 11 that the values furnished by the five different observers do not differ significantly.

EXPERIMENT II.

In the field the aspect of coverage by sampling points, previously mentioned, is of considerable moment. If, for example, it were wished to make a survey of the vegetation of a paddock or field of 10 morgen, i.e. 102,608 square yards (85,653·2 sq. m.), in which the mean cross sectional length of the vegetation clusters was estimated to be considerably less than 4 feet (1·22 m.), it might, on first thought, be considered advantageous to use a pair of opposite spokes on the wheel to furnish points 4·71 feet (14·36 m.) apart in the lines.

To obtain a regular systematic sample, the sampling lines should then also be 4·71 feet apart. In this way a sample of about 41,600 points would be obtained for the field or paddock, whereas only 2,000 points would probably be necessary to furnish the desired accuracy.*

Further, a distance of 37 miles (59·5 Km.) would have to be walked to complete the survey. Alternatively, since the length of the axle is 3·54 feet (1·08 m.), it might be decided to use both wheels of the apparatus (two spokes on each), and to employ an additional observer for the second wheel. The distance walked in the survey would then be halved; but this would still be excessive, and the time taken would be prohibitive.

Were a single spoke to be used on one wheel only, to furnish points 9·42 feet (2·87 m.) apart, and with sampling lines 9·42 feet apart, about 10,404 points would be obtained from the survey. The distance walked would be 18·6 miles (29·9 Km.). The number of points recorded, and the distance walked, may be reduced further by recording the points furnished by every second or third revolution of the wheel only, and by spacing the lines accordingly; but even so the distance walked would be greater than desirable. (For further discussion of this aspect see Appendix.)

In view of these considerations it was decided to test whether, with a given number of points, sufficiently accurate estimates could be obtained by spacing the points 9·42 feet (2·87 m.) apart in the lines, but with the lines very much further apart, in order to reduce both the distances walked and the time spent on the survey.

In a stand of mixed Karoo vegetation (different from that of Expt. I) a rectangle, 1,272 by 79 yards (1,163·1 × 72·2 m.), i.e. approximately 10 morgen (8·6 hectares), was pegged off, and 25 lines, 9·42 feet (2·87 m.) apart, parallel to the long axis of the rectangle were set out in it. By using one spoke in one wheel of the apparatus 405 points, 9·42 feet (2·87 m.) apart, were located along each line to furnish a total of 10,125 points for the whole area. The rectangle was divided into five equal grids by four equidistant lines parallel to the short axis so that 2,025 points, 9·42 by 9·42 feet (2·87 × 2·87 m.) apart, were located in each grid. The strikes registered along each line within each grid were recorded separately.

The results of the survey are presented in Tables 12 to 16.

By taking together any two contiguous grids, and by grouping the data of alternate lines (i.e. odd lines and even lines) separately, two comparable samples of 2,106 and 1,944 points respectively are obtained. Thus, grids 1 and 2, 2 and 3, 3 and 4, 4 and 5, may be so treated to furnish four pairs of such samples. The grids may be further considered in threes: 1, 2, 3; 2, 3, 4; 3, 4, 5; and the data of every third line grouped separately to furnish three sets of three comparable samples each. Two groups of four grids each may be formed in this way, and the data of every fourth line grouped separately to furnish two sets of four comparable samples each. Finally, the five grids may be taken together, and the data of every fifth line grouped separately to furnish a single set of five comparable samples. By this process a series of sets of comparable samples is obtained in which the points are spaced 9·42 feet (2·87 m.) apart in the lines, but in which the lines are spaced 18·84 feet (5·74 m.), 28·26 feet (8·61 m.), 37·68 feet (11·48 m.), and 47·10 feet (14·35 m.) apart respectively.

The results of these tests, in respect of total cover, are given in Table 17.

* The aspect of the number of points required to furnish a given accuracy is dealt with later in this paper.

TABLE 12.—*Grid* 1.—*Strikes per Line of* 81 *Points.*

Species.	Lines.																									Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Aptosimum depressum	–	1	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	3
Aristida spp	2	1	4	2	2	–	4	2	–	1	–	–	1	2	2	–	1	–	–	1	–	–	–	1	–	25
Aster muricatus	–	1	–	1	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	1	1	–	6
Blepharis villosa	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Bulbostylis humilis	1	1	1	1	2	–	–	–	–	–	–	2	1	–	1	1	1	2	1	–	–	1	1	2	1	20
Chrysocoma tenuifolia	–	–	1	1	–	3	4	1	2	3	2	5	1	2	2	5	3	2	2	1	3	1	2	1	2	49
Crassula sp	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
Cynodon incompletus	1	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Enneapogon brachystachyus	1	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	4
Eragrostis lehmanniana	2	–	–	1	–	–	–	–	–	–	–	–	–	1	1	1	2	–	1	–	–	2	1	1	2	15
Eriocephalus spinescens	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Gazania sp	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1
Gnidia polycephala	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
Ifloga paronychioides	2	–	1	–	1	2	1	1	1	–	1	3	–	1	–	–	–	1	1	–	2	1	2	–	–	21
Indigofera alternans	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Lycium oxycladum	1	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	4
Nestlera conferta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
Osteospermum leptolobum	–	–	–	–	–	–	–	–	–	–	1	1	2	–	–	–	–	–	–	–	–	–	–	–	–	4
Oxalis depressa	1	2	–	1	1	–	1	2	2	3	2	3	2	2	–	1	–	1	–	2	–	–	1	–	–	27
Pentzia incana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
Phymaspermum parvifolium	1	–	1	1	–	–	–	–	2	1	1	–	1	–	1	1	–	–	–	1	–	–	–	–	2	13
Pteronia glauca	–	–	–	–	–	–	1	1	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	4
P. glomerata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
P. tricephala	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Salvia clandestina	1	–	1	–	–	2	–	2	5	1	1	–	2	–	–	–	1	1	1	–	1	–	1	–	1	21
Sporobolus ludwigii	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Stachys linearis	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	2
Tragus koelerioides	–	1	2	2	2	1	1	1	1	1	1	–	2	1	–	1	–	–	–	–	1	1	–	–	1	20
T. racemosus	2	1	–	–	1	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	1	7
Ursinia annua	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	2
Wahlenbergia androsacea	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2
Walafrida geniculata	–	–	1	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1	–	–	–	–	4
W. saxatilis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1	–	–	–	–	2
TOTALS	15	9	13	13	10	9	14	14	14	11	12	14	13	15	8	11	9	7	7	5	11	6	12	7	12	

GRAND TOTAL..... 271
Cover per cent..... 13·38

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TABLE 13.—*Grid 2.—Strikes per Line of 81 Points.*

Species.	Lines.																									Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Aptosimum depressum	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Aristida spp	2	–	–	3	3	–	–	2	–	–	–	–	2	1	–	–	1	1	–	2	–	–	1	–	1	19
A. vestita	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Aster muricatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Berkheya rigida	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–	2
Blepharis villosa	1	–	–	–	1	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
Bulbostylis humilis	–	–	–	–	–	2	–	–	–	–	1	–	1	–	–	1	1	–	–	–	–	–	–	–	–	6
Chrysocoma tenuifolia	2	3	–	–	–	2	–	–	1	–	3	4	2	–	–	5	–	–	1	1	1	–	–	3	–	28
Crassula sp	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
Eragrostis lehmanniana	–	–	–	1	–	–	–	–	–	–	1	–	–	1	–	1	–	–	–	–	–	–	–	–	–	4
Eriocephalus glaber	–	–	–	–	–	–	–	–	–	2	–	–	–	–	1	–	–	–	–	–	1	1	–	–	1	6
E. spinescens	–	–	–	–	–	1	2	–	–	2	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	6
Euphorbia prostrata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1
Helichrysum luciloides	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Hermannia coccocarpa	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2
Ifloga paronychioides	–	–	–	–	1	–	–	–	–	–	–	2	1	–	–	–	–	1	–	1	1	1	–	2	–	10
Indigofera alternans	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	2
Lycium oxycladum	2	–	–	3	–	–	–	–	1	–	–	–	–	2	–	–	–	–	1	–	–	–	–	1	–	10
Oxalis depressa	–	1	1	2	–	1	–	2	–	–	–	2	–	–	–	1	–	1	–	–	1	2	1	–	1	16
Pentzia incana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1
Phymaspermum parvifolium	–	1	–	1	1	–	1	1	1	–	–	2	–	–	–	1	–	–	–	–	–	1	1	1	–	12
Plinthus karrooicus	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Pteronia glauca	–	2	1	1	–	–	1	3	1	3	2	2	1	–	1	–	–	1	–	–	–	–	–	1	–	20
P. glomerata	–	1	1	2	1	1	1	1	2	1	1	–	–	–	–	–	1	1	1	–	2	–	–	–	–	17
Salsola nigrescens	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Salvia clandestina	–	–	–	–	1	–	3	2	1	2	–	2	–	–	1	–	–	–	–	–	–	1	1	–	1	15
Stachys linearis	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Tragus koelerioides	1	1	4	2	–	1	3	4	2	–	4	–	–	1	–	1	1	–	1	1	–	–	1	–	–	28
T. racemosus	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	4
Thesium hystrix	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Wahlenbergia androsacea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	2
Walafrida geniculata	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
W. saxatilis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	2
TOTALS	8	10	8	16	9	9	13	15	11	12	12	14	9	5	4	11	7	8	5	5	9	6	6	8	7	

GRAND TOTAL.. 227
Cover per cent..... 11·21

TABLE 14.—*Grid* 3.—*Strikes per Line of* 81 *Points.*

Species.	Lines.																									Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Aptosimum depressum	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	2	–	–	4
Aristida spp	1	2	1	3	–	–	2	–	1	3	1	3	–	–	1	2	–	1	1	1	–	–	–	–	1	24
A. vestita	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Aster muricatus	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Bulbostylis humilis	–	–	–	2	–	2	–	2	–	–	–	2	2	–	–	1	–	–	–	1	2	–	2	–	1	17
Chrysocoma tenuifolia	1	1	1	1	3	2	2	2	1	4	4	1	3	1	2	3	1	1	3	2	1	–	4	2	1	47
Crassula sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	1	–	–	1	4
Cynodon incompletus	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2
Eragrostis lehmanniana	–	1	–	1	–	–	–	2	–	–	–	–	–	1	1	1	–	–	–	–	–	1	–	–	–	8
E. bergiana	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Eriocephalus spinescens	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Gazania sp.	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Gnaphalium sp.	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Helichrysum dregeanum	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	2
Hermannia coccocarpa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	2
Ifloga paronychioides	3	–	3	–	1	1	1	–	2	2	1	2	2	2	2	2	1	1	–	1	3	1	2	–	1	34
Indigofera alternans	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Lycium oxycladum	–	–	1	–	–	–	–	1	1	1	2	1	–	–	1	–	1	–	1	1	–	–	1	1	1	14
Nenax microphylla	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
Nestlera humilis	–	–	1	1	–	2	–	–	1	–	2	–	1	1	–	–	1	–	–	–	–	–	–	–	–	10
Oxalis depressa	–	1	1	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	4
Phymaspermum parvifolium	–	3	1	–	–	–	–	1	1	1	3	3	1	–	1	–	–	–	1	3	1	–	–	–	1	21
Pteronia glauca	–	–	–	–	1	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1	–	–	–	4
P. glomerata	1	1	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5
Salvia clandestina	1	1	–	–	1	1	–	1	–	–	–	–	–	1	1	–	–	1	–	1	–	–	1	–	2	12
Tragus koelerioides	1	2	–	–	1	–	–	2	–	1	–	1	–	1	1	2	2	–	–	–	2	–	1	–	–	17
T. racemosus	–	–	–	–	–	–	–	–	2	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	3
Ursinia annua	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Wahlenbergia androsacea	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	4
Walafrida geniculata	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
TOTALS	8	15	10	10	7	10	7	12	12	13	15	17	10	7	10	12	6	6	7	11	12	4	13	5	10	

GRAND TOTAL.. 249
Cover per cent..... 12·30

TABLE 15.—*Grid* 4.—*Strikes per Line of* 81 *Points.*

Species.	Lines.																									Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Aptosimum depressum	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Aristida spp	2	1	2	–	1	–	–	1	–	–	–	3	–	–	1	–	–	–	1	1	2	–	1	1	1	18
Aster muricatus	–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	3
Berkheya rigida	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1
Bulbostylis humilis	2	–	–	1	3	1	–	–	–	–	–	2	–	–	2	2	2	2	2	–	1	1	–	–	2	23
Chloris virgata	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Chrysocoma tenuifolia	1	1	–	4	1	1	3	1	2	3	3	1	3	2	1	2	1	1	–	1	4	–	3	1	1	41
Crassula sp	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–	2	–	4
Cynodon incompletus	–	1	–	–	–	–	1	–	3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
Eragrostis lehmanniana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	2	–	–	–	4
Galenia sp	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Gazania sp	2	1	–	1	1	–	–	–	1	3	1	–	–	–	1	1	1	1	–	–	–	–	1	–	–	15
Gnaphalium micranthum	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Helichrysum dregeanum	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	2
H. lucilioides	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Hermannia coccocarpa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
Ifloga paronychioides	3	1	4	3	2	2	2	4	2	2	2	2	2	2	2	1	2	–	–	1	1	4	2	3	4	53
Lightfootia tenella	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Lycium oxycladum	–	–	1	–	1	1	1	–	–	1	2	1	–	–	1	–	–	–	1	–	–	–	–	–	–	10
Nenax microphylla	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1
Nestlera humilis	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–	3
Osteospermum leptolobum	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Oxalis depressa	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Pentzia incana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
Phymaspermum parvifolium	1	–	–	1	1	1	1	1	1	1	4	3	–	–	1	–	–	1	1	1	1	1	1	1	1	24
Pteronia glauca	–	1	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	3
P. glomerata	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
P. tricephala	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1
Salsola nigrescens	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	2
Schismus fasciculatus	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Salvia clandestina	1	–	1	–	–	2	–	1	–	–	1	–	–	1	–	1	–	2	1	1	–	1	–	–	2	15
Stachys linearis	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Tragus koelerioides	–	2	–	–	–	–	1	1	1	–	1	1	1	1	1	–	1	–	2	–	–	1	–	–	2	16
T. racemosus	–	1	–	–	2	1	–	–	–	1	–	1	–	–	–	–	–	1	1	1	1	–	–	–	–	10
Trichodiadema pomeridianum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1	2
Wahlenbergia androsacea	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	2	–	–	–	–	–	–	–	–	–	3
Walafrida geniculata	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1
W. saxatilis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
TOTALS	12	10	9	12	13	10	9	11	14	14	17	17	9	7	12	12	8	11	8	8	13	9	11	8	15	

GRAND TOTAL.. 279
Cover per cent..... 13·78

TABLE 16.—*Grid 5.—Strikes per Line of* 81 *Points.*

Species.	Lines.																									Totals.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Aptosimum depressum	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Aristida spp	1	–	–	–	1	–	–	–	–	–	1	–	2	1	–	–	–	–	1	–	1	–	1	–	1	10
Aster muricatus	–	3	–	–	–	–	–	1	1	1	–	1	–	–	–	1	–	–	1	–	–	–	–	1	2	12
Berkheya rigida	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Blepharis villosa	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Bulbostylis humilis	1	1	1	2	1	–	–	1	–	–	1	–	–	2	1	–	–	–	1	1	1	2	2	1	–	19
Chrysocoma tenuifolia	–	–	2	–	–	1	2	–	–	1	2	–	–	–	–	3	–	1	–	–	2	1	–	–	3	18
Crassula sp	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1	–	–	2
Cynodon incompletus	–	1	–	–	–	1	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	5
Eragrostis lehmanniana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	2	–	1	4
Gazania sp	1	1	2	–	3	4	–	–	3	–	1	–	–	2	1	2	–	–	–	–	–	–	–	–	2	22
Gnaphalium micranthum	–	–	–	–	–	–	–	1	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
Geigeria passerinoides	–	–	–	–	–	–	–	–	–	–	–	2	1	–	–	–	–	–	–	–	–	–	–	–	–	3
Hermannia coccocarpa	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	2
Ifloga paronychioides	1	3	–	2	3	–	1	2	4	3	1	2	–	2	3	2	4	4	–	2	2	3	5	1	3	53
Indigofera alternans	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1	–	–	2
Lepidium divaricatum	–	–	–	–	–	1	1	–	1	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	5
Lepturella capensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	1	4	–	–	2	1	2	1	13
Lycium oxycladum	2	–	–	–	1	–	–	1	–	1	–	–	1	–	1	1	–	–	–	1	–	–	–	1	–	10
Medicago aschersoniana	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	1	–	–	–	–	1	–	–	–	4
Nestlera humilis	–	–	–	–	–	–	1	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
N. conferta	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Osteospermum leptolobum	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Oxalis depressa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	1	–	–	–	1	–	4
Pentzia annua	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
P. incana	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	2
Phymaspermum parvifolium	–	1	–	–	–	1	–	–	1	2	3	–	3	–	1	–	2	–	–	1	2	2	2	2	5	28
Plinthus karrooicus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
Pteronia glauca	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Salsola nigrescens	1	1	1	–	1	–	–	–	–	1	1	–	3	1	1	1	–	–	–	–	–	–	1	–	1	14
Schismus fasciculatus	–	1	1	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
Salvia clandestina	–	–	–	–	–	2	–	1	–	1	–	2	–	1	–	–	–	–	–	–	–	–	–	–	–	7
Sutera pinnatifida	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
Tragus koelerioides	–	–	–	1	–	–	1	–	1	1	2	–	–	1	2	1	–	1	–	–	2	–	1	3	–	17
T. racemosus	–	–	1	1	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	4
Trichodiadema pomeridianum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	2
Thesium hystrix	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Ursinia annua	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
TOTALS	8	12	8	7	10	11	6	12	14	14	16	13	12	11	13	13	9	8	8	7	11	12	19	13	20	

GRAND TOTAL.. 287
Cover per cent..... 14·17

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From Table 17, in which the standard deviation of the five samples of the whole area is also compared with that calculated for a binomial distribution of five samples of 2,025 random points each, it is seen that the estimates of the mean (percentage cover) furnished by the samples with widely spaced lines (but with the points 9·42 feet apart in the lines) were as reliable as any that could be obtained from any method of sampling with 2,025 points. Appropriate tests reflected no significant deviations from the weighted means in any of the groups of samples.

TABLE 17.

Pairs of Grids.				Groups of Three Grids.			
Grids.	Sample.	Cover per cent.	Weighted Mean.	Grids.	Sample.	Cover per cent.	Weighted Mean.
1 and 2...	1	12·25	12·30	1–3.....	1	12·35	
	2	12·35			2	12·40	12·30
2 and 3...	1	11·16	11·76		3	12·14	
	2	12·40		2–4.....	1	12·25	
3 and 4...	1	13·15	13·04		2	12·35	12·43
	2	12·91			3	12·71	
4 and 5...	1	14·43	13·98	3–5.....	1	12·85	
	2	13·48			2	13·73	13·42
					3	13·73	

Groups of Four Grids.				Group of Five Grids.			
Grids.	Sample.	Cover per cent.	Weighted Mean.	Grids.	Sample.	Cover per cent.	Weighted Mean.
1–4.....	1	12·92	12·67	1–5.....	1	14·17	
	2	11·47			2	12·64	
	3	12·45			3	13·14	12·97
	4	13·79			4	12·05	
2–5.....	1	12·92	12·87		5	12·84	
	2	12·04					
	3	12·65		Experimental S.D..			0·78
	4	13·84		Expected (binomial) S.D..			0·75

NOTE.—The "weighted mean" values are furnished by the regular pattern of spread of the sampling points, i.e. the distance between points in the lines equal to the distance between the lines.

Similar results were obtained from the data of several of the more common species tested in the same way, and from similar experiments repeated in two somewhat different kinds of mixed Karoo vegetation.

When areas of this size [approximately 10 morgen (8·6 hectares)] are to be surveyed, by spacing the lines wide apart, but with the points relatively closely spaced within the lines, much time and effort is saved.* It will be obvious, however, that this process cannot be extended indefinitely as larger areas are to be surveyed, or even that the spacing employed in the experiment described

will be suitable in all instances of equal area. Since the distance to which the spacing of the lines can safely be extended will doubtless depend upon the degree of homogeneity of the vegetation, the requisite spacing will have to be determined for each broad type of vegetation separately, at the outset, before adoption of any espacement for routine procedure. Larger areas, or areas comprising two or more types of vegetation, will necessitate a larger number of points to furnish the same accuracy of estimate.

The application of the method to different purposes will be discussed later in this paper.

LIMITS OF ACCURACY.

Provided the sampling points are sufficiently widely spaced relative to the size of the individual units or clusters of vegetation, and the area surveyed is adequately covered by the spread of the sampling points, the limits of error or an estimate of cover will depend upon the basal density of the vegetation and the number of points employed. Since it has been shown that the estimates obtained by the wheel-point method conform to the binomial distribution, the limits of error of an estimate of cover in relation to the number of points and density of the vegetation may be calculated directly from the formula, $\sigma = \sqrt{npq}$, in respect of the number of strikes, or, $\sigma = 100\sqrt{\frac{pq}{n}}$, in respect of the percentage cover, where—

σ = standard deviation;

n = number of points;

p = probability of a strike by a single point $= \frac{\text{basal area of vegetation}}{\text{total area of soil surface}}$;

q = probability of a miss by a single point.

The limits of error calculated in this way are presented in Figure 5, from which they can be read off directly.

From the graphs it will be seen that, with a given number of points, the limits of error, expressed in terms of percentage of estimate, become narrower as the density (cover) of the vegetation increases (i.e. up to 50 per cent cover); or, alternatively, the number of points required to furnish a given accuracy diminishes as the cover increases. In practice, however, it is more convenient to express the error in terms of actual percentage cover, rather than as a percentage of the estimate; and although the number of points required to furnish a given accuracy varies inversely with the cover, the total cover of the vegetation is not the only, or even the most important, criterion of the survey: even though the total cover may be high, that of the different species whose values it will be wished to determine separately will probably exhibit a wide range and will complicate the decision, therefore, of the number of points to be employed. This is further complicated by the consideration of adequate coverage of the area to be surveyed by the spread of the sampling points, as discussed earlier in this paper. In practice it has been found that 2,000 points is a convenient number for most purposes.

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* With practice, it has been found that a survey of 2,000 points in mixed Karoo vegetation can be completed in two hours.

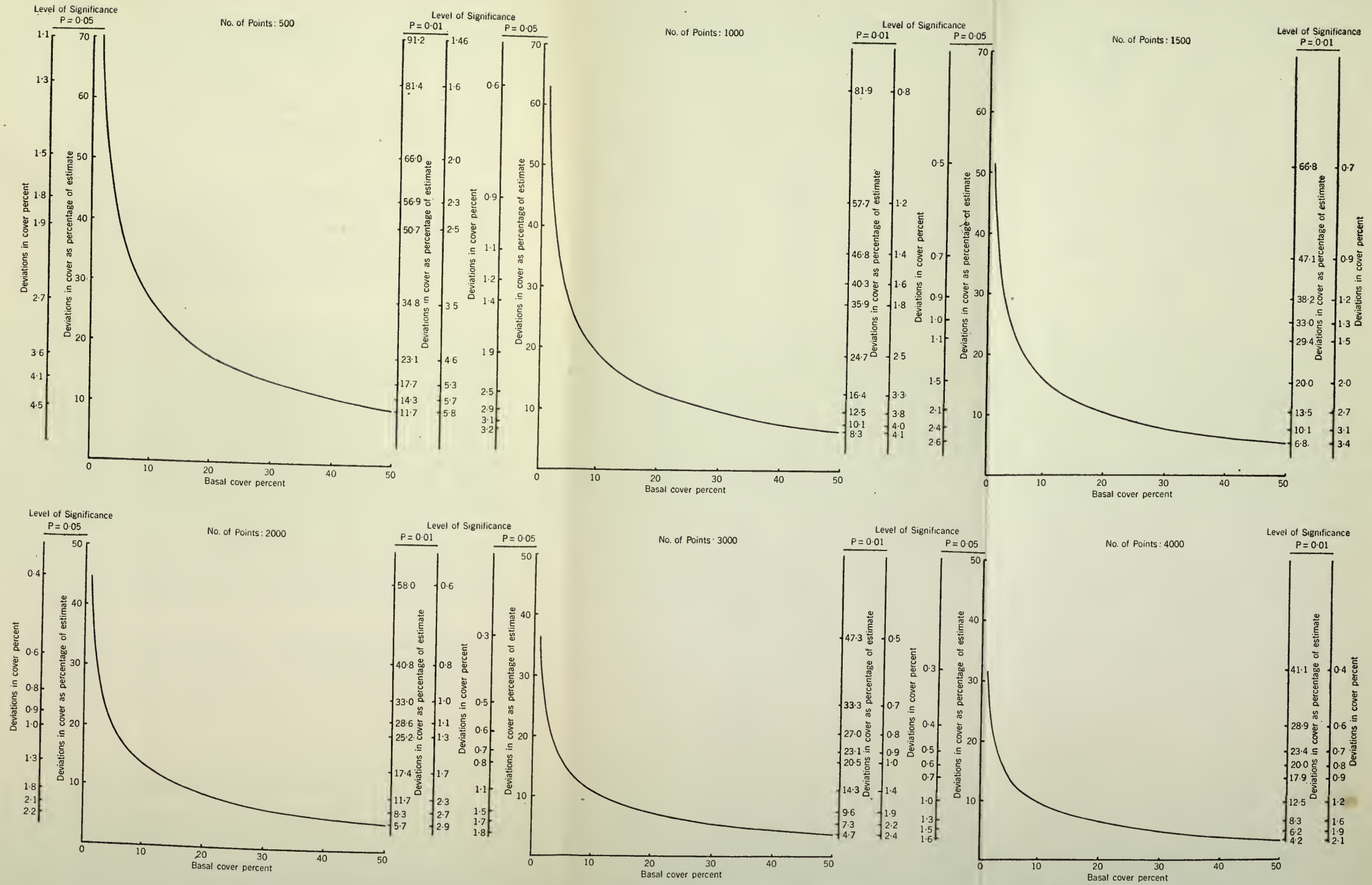

FIG. 5.—Graphs showing the limits of error of estimates, at P = 0·05 and P = 0·01, for samples of 500 to 4,000 points, and for values of cover from 1 to 50 per cent.

RULES OF PROCEDURE:

For those who may wish to use the wheel-point method of survey, the following rules of procedure are presented:—

(1) Formulate a clear definition of what is to be regarded as a strike or a miss: the definition presented in this paper need not necessarily be accepted, but whatever definition is adopted must be strictly adhered to.

(2) Decide the approximate level of accuracy desired and the number of sampling points therefore required. This will be more readily decided after a trial survey of a small area with, say, 2,000 points has been made to determine the approximate value of cover of the vegetation. The requirements may then be calculated from the second moment of the binomial distribution, or may be read off from the graphs of Figure 5.

(3) Decide how the points are to be distributed over the area to be surveyed. If, for example, the area is approximately 400 by 200 yards (365·8 × 182·9 m.), and the individuals and/or clusters of vegetation are less than nine feet (2·74 m.) in diameter, and the number of points required is approximately 2,000, it will probably be decided to use one marked spoke in one wheel of the apparatus to furnish points 9·42 feet (2·87 m.) apart in the lines. A single line (traverse) parallel to the long axis of the area will furnish thus 127 points, and 16 such lines (traverses) will therefore be required to furnish approximately 2,000 points. The shorter axis of the area is approximately 200 yards (182·9 m.), and the lines will therefore be distributed 12·5 yards (11·4 m.) apart along that axis of the area. Markers should be fixed at each end of the area to indicate the positions of the lines and to enable the apparatus to be drawn from marker to corresponding marker. The exact number of points located in the survey will be registered by the counter affixed to the apparatus; the strikes only need therefore be recorded.

(4) If doubts are held regarding the adequacy of the coverage afforded by the suggested pattern of spread of the points in respect of the particular type of vegetation, the procedure followed in Field Experiment II will have to be adopted initially to test it, before routine surveys are begun.

EXAMPLE OF THE METHOD IN USE.

An example of the method in use is furnished by the results of a survey of two experimental paddocks presented in Table 18.

The paddocks, to which different grazing treatments have been applied for a number of years, are 10 morgen (8·6 hectares) each, and are situated in mixed Karoo vegetation as illustrated in Plate 1.

TABLE 18.—*Survey of the Vegetation of Two Paddocks*: 2,000 *Points in Each Paddock*; *Lines* 47·1 *ft.* (14·35 *m.*) *apart*; *Points* 9·42 *ft.* (2·87 *m.*) *apart within Lines.*

Species.	Paddock 1.		Paddock 2.
Aptosimum depressum	0·05		0·25
Aristida spp.	6·70	S	1·70
A. vestita	—		0·05
A. obtusa	0·10		—
Arthrosolen polycephalus	0·05		—
Aster filifolius	0·10		—
A. muricatus	0·10	S	0·45
Berkheya rigida	—		0·15
Blepharis villosa	0·20		0·05
Chrysocoma tenuifolia	0·65	S	1·65
Chloris virgata	0·20	S	—
Cryptostemma calendulaceum	—		0·05
Cynodon incompletus	0·60		0·40
Digitaria argyrograpta	0·05		—
Eragrostis bicolor	0·10		—
E. obtusa	0·05		0·15
E. lehmanniana	1·70	S	0·30
Eriocephalus glaber	0·15		0·05
E. spinescens	—	S	0·20
Euphorbia prostrata	—		0·05
Helichrysum dregeanum	—		0·10
H. parviflorum	0·10		—
Ifloga paronychioides	—		0·10
Indigofera alternans	0·25	S	—
Lycium spp.	0·10		0·40
Nenax microphylla	0·10		—
Nestlera humilis	0·10		0·15
Pentzia incana	0·20		0·10
Phyllaspermum parvifolium	1·35	S	0·75
Plinthus karrooicus	—		0·05
Pteronia glauca	0·10		0·20
P. glomerata	—	S	0·40
Pterothrix spinescens	0·10		—
Salsola negrescens	0·15		0·20
Salvia clandestina	—	S	0·55
Sporobolus fimbriatus	0·05		—
Tragus koelerioides	0·60	S	1·45
Trichodiadema pomeridianum	0·10		—
Walafrida saxatilis	0·40		0·30
TOTALS	14·50	S	10·25

Values represent percentages basal cover.
S = significant at P = 0·05.

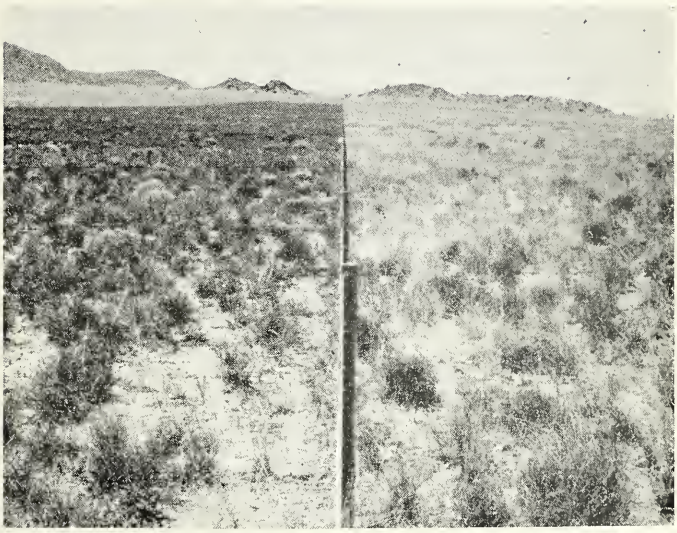

Plate I.

View of two experimental paddocks in mixed Karoo vegetation. The two paddocks have been differentially grazed for a number of years. On the left is Paddock 2, and on the right, Paddock 1, of Table 18. The light coloured grasses seen between the small shrubs, in Paddock 1 especially, are species of *Aristida* and *Eragrostis* of which significantly higher values are reflected for this paddock in Table 18.

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Differences between corresponding values of the two paddocks may be tested for significance in either of two ways:—

(1) By calculating—

$$t = \frac{p_1 - p_2}{\sqrt{\frac{p_1q_1 + p_2q_2}{n - 1}}},$$

where—

p_1 = probability of a strike by a single point in paddock 1;
p_2 = probability of a strike by a single point in paddock 2;
$q_1 = 1 - p_1$;
$q_2 = 1 - p_2$;
n = number of sampling points in each paddock;

and by finding the required level of significance from the appropriate table of t-values.

(2) By calculating—

$$\chi^2 = \frac{\frac{(x_1 - x_2)^2}{2}}{npq},$$

where—

x_1 = number of strikes in paddock 1;
x_2 = number of strikes in paddock 2;
n = number of sampling points employed in each paddock;
p = mean probability of a strike by a single point of both paddocks combined;
$q = 1 - p$.

The significance levels may then be read off from a table of χ^2 values.

For the rapid determination of significance between corresponding values of two paddocks, graphs may be drawn from the following formula:—

$$p_1 = \frac{t^2 + 2vp_2 \pm \sqrt{t^2\,[-4\,(t^2 + 2v)p_2^2 + 4(t^2 + 2v)p_2 + t^2]}}{2(t^2 + v)},$$

where $v = n - 1$ and the other symbols are the same as those of the first method of calculation; and n = the number of points employed in each paddock, provided this number is the same for both paddocks.

For the benefit of field workers, Figures 6 to 23 have been constructed for values of cover ranging from 0 to 1, 1 to 10, and 10 to 50 per cent, for $n = 500$, 1,000, 1,500, 2,000, 3,000 and 4,000 respectively, at the significance level of 0·05 for which, in this case, $t = 1{\cdot}96$. When a co-ordinate point plotted from any corresponding pair of values of two paddocks (or areas surveyed) falls outside the hatched area of the graph, the difference between those values is significant. Similar graphs for any value of n, at any desired level of significance, can be readily constructed from the formula given.

From the application of any one of these methods to the data of Table 18 it will be seen that the significance of the differences in total cover, and of the cover of the constituent species, produced by the differential treatments, are readily detected by the survey.

The adequacy of the coverage afforded by the pattern of spread of the points had previously been tested in respect of the general type of vegetation.

USES OF THE WHEEL-POINT METHOD.

Surveys of vegetation, especially of pastoral ranges, are usually made with one or more of several definite purposes:—

(1) In experimental work, in which separate areas, fields, or paddocks, are accorded different treatments, it is required to measure in detail—
   (*a*) the nature and magnitude of any changes that may take place in the vegetation of any area in time;
   (*b*) any differences that may exist at any time in the vegetation of the different areas as a result of the different treatments.

(2) In the restoration and conservation of range lands it is required to study the progress of the vegetation of relatively large areas, in time; but it is not usually necessary to make detailed comparisons between the vegetation of different areas.

(3) Survey of the range for description, classification, and assessment of grazing value.

For the first purpose outlined it is necessary to determine, as accurately as possible, the composition and cover of the vegetation of each whole area; but as such areas are usually fairly small this presents no particular difficulties, and the survey is readily accomplished with the wheel apparatus in the way described earlier in this paper. Comparisons of the results of the surveys of several different areas (paddocks) are made first by the method of analysis of variance, in which, however, the variance within areas is calculated directly from the binomial distribution with p = mean survey value of the different areas. The F table is entered with n_1 = number of paddocks less 1, and n_2 = infinity. This amounts in fact to a χ^2 test, and according to its findings the data of any two areas may then be compared in the way described in the previous subsection of this paper.* It will be noted, therefore, that for the purpose of the calculation replicate surveys of each area are not necessary.

For the second purpose, a complete survey of the vegetation of the whole area with the wheel apparatus would (if the area were large) demand excessive time and effort; but since the chief purpose is to measure changes in the vegetation in time, to detect trends of change, it will usually suffice to select a more or less representative traverse through the area and make repeated surveys of this traverse to serve as a measure of trend of the changes in the vegetation of the whole area. Several such traverses through the area may be beaconed if necessary.

For the last purpose the method of survey may be adapted as required: it is usual to distinguish visually the different plant communities or vegetation types, and to make several traverses with the apparatus through each.

Limitations of the wheel apparatus are that it cannot be used successfully in tall scrub vegetation, or woodland, to furnish a complete survey of the vegetation, although it may be employed effectively for surveys of the ground vegetation in the interspaces of such communities; nor can it, for obvious reasons, be used successfully on rocky or boulder-strewn slopes, although it has been found to be effective on ordinary stony ground, provided the marked spoke is not prevented from penetrating to the soil surface between the stones.†

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* For fuller explanation see Appendix.

† P. W. Roux (Pasture Research Officer, Grootfontein College of Agriculture) has successfully adapted the method for use on rock-strewn hill slopes by using an ordinary surveyor's chain stretched in parallel lines across the area to be surveyed. Equidistant points are located at the desired intervals by passing a thin, metal rod vertically through predetermined links and recording the strikes obtained.

It must be recorded here that, although the method has been specially developed for use in semi-open range lands, it has been used with equal success in fairly dense grassland; but since it is more difficult in this vegetation to distinguish at a glance between individual tufts, the operation is necessarily slower.

DISCUSSION.

The results of the experiments described in this paper have shown that a sample supplied by a number of systematic points, located by means of a wheel apparatus, furnishes a direct and reliable estimate (in conformance with the binomial distribution) of the basal cover and composition of the vegetation of the area surveyed; and provided the points are sufficiently widely spaced relative to the size of the individuals or clusters, and the area surveyed is adequately covered by the spread of the sampling points, the manner (or pattern) in which the units of vegetation are distributed over the area has no influence on the accuracy of the estimate. Considerations therefore of homogeneity, heterogeneity, over-dispersion, under-dispersion; or randomness of the vegetation, that appear to have troubled ecologists, are of significance only in so far as they may influence the requisite spread of the sampling points. The method employed is simple, rapid and direct; and provided a definition of what constitutes a strike or a miss is formulated clearly and adhered to, there is little chance of error on this score; this was demonstrated by the close agreement between the results obtained by five different observers. (Field Expt. 1.)

In comparison with the wheel-point method of survey, the conventional point-quadrat method has many disadvantages: the close grouping of a number of points in the bridge, or frame, presumably intended to reduce the number of independent stations (positions) to be occupied by the bridge, or frame, to furnish the requisite number of points, defeats its object in that the high degree of correlation between the points within the bridge, or frame, must necessarily furnish a seeming accuracy that is misleading [as borne out by the work of Corby (1950) and the results of the laboratory experiments described in this paper]; and, further, the coverage of the area by the sampling points will tend to be inadequate. Reduction to a single point per bridge, or frame, on the other hand, while conforming to statistical requirement, would make the method exceptionally laborious. A further practical disadvantage of the method lies in the casting of a marker and the subsequent possibility of inadvertent positional manipulation of the bridge, or frame, as for example, when the marker comes to rest obliquely against a stiff plant, stone, or other obstruction.

Among various adherents of the point-quadrat method there appears to be some confusion about what exactly is being measured: whether the measurements are of area (basal or canopy cover), or of volume, or of a combination of both; and there seems also to be some doubt whether the first, the last, or all plants (leaves or twigs), touched by the pin in passage to the soil surface should be recorded; whether the sample furnished therefore is a point or a line. Crocker and Tiver (1948) discuss attempts to convert measurements of cover to yield or quantity of herbage by the application of numerical factors, and various workers have tried to " improve " the technique by using sloping pins: Corby (1950) even suggests the use of horizontal pins; though what it is that is actually being measured in such cases is not clear. For some reason there appears to be a tendency to regard a miss as a waste of a point, rather than as an indispensable sample in the determination of the true status of the vegetation. It may be that greater value is attached to the relative volumes of the different species comprising the vegetation than to the extent to which the soil is covered by the vegetation and its constituent species.

In view of the apparent confusion of concepts, it is essential that it should be clearly decided at the outset what it is actually wished to determine. The experiments described in this paper are concerned with the measurement of basal cover only; and, with a knowledge of the growth forms and habits of the species comprising the vegetation, such figures are of decided value. Should it be wished to measure volume, a different technique (one that is at present receiving consideration) should be employed.

CONCLUSIONS.

(1) Systematic samples with points in straight lines furnish direct unbiassed estimates of the mean with standard deviation that conforms to the binomial distribution, irrespective of the pattern of spread of the vegetation, provided that—

(*a*) the distance between the points within and between the lines is greater than the cross sectional lengths of the individuals, or contiguous clusters of individuals, comprising the population to be sampled;

(*b*) the area to be sampled is adequately covered by the spread of the sampling points.

(2) Provided that adequate coverage of the area by the spread of the sampling points is afforded, the points need not necessarily be arranged in a pattern of squares, i.e. with the distance between points in the lines equal to the distance between the lines.

(3) When the distance between the sampling points is less than the cross sectional lengths of the individuals or clusters of vegetation, the estimates of variance obtained are too low and furnish a seeming accuracy that is misleading. (The point-quadrat method is subject to error on this score.)

(4) If the coverage afforded by the spread of the sampling points is inadequate, the estimates of the mean furnished may be unreliable.

(5) The degree of accuracy of an estimate is dependent upon the number of points employed in the sample and upon the basal density (percentage cover) of the vegetation, and may be calculated direct from the second moment of the binomial distribution. In practice 2,000 points have been found to be adequate to most requirements.

(6) A simple wheel apparatus is a suitable device for making rapid determinations of the composition and cover of semi-open grassland and mixed Karoo vegetation according to the method of systematic sampling points.

(7) The wheel-point method of survey is simple to operate, and the estimates furnished by it are uninfluenced by the personal bias or skill of the operator or observer: provided what constitutes a strike or a miss is clearly defined and adhered to, equally reliable estimates are furnished by different observers who need possess no special skill or training.

(8) The method is readily adapted to various purposes in the field.

SUMMARY.

Studies were made of—

(1) the validity of a method of systematic sampling, with points in straight lines, for the determination of the basal cover of vegetation and its constituent species;

(2) the suitability of a simple wheel apparatus for obtaining such samples.

Experiments in the laboratory and in the field were conducted.

LABORATORY EXPERIMENTS.

Experiment 1.

Large numbers of circular discs of three different, known, sizes were punched from cardboard sheets of three different colours so that within each size group there were equal numbers of discs of each of the three different colours. The numbers of discs of each size and colour was such that, when distributed on a table top, 125 by 46 inches (317·49 × 116·84 cm.), the discs of any size/colour group covered 5·3 per cent of its surface. There were thus nine different groups of discs having a combined total area of 47·7 per cent of the area of the table top. The nine groups of discs were successively distributed on the table without any discs overlapping. After each successive distribution of discs, a sample of 1,000 points was obtained by means of a miniature wheel of which one marked spoke was used for locating the points. In all, thus, nine samples of 1,000 points each were obtained.

The estimates of cover furnished by the samples were in close agreement with the actual (known) values, but the variance in respect of the large discs was significantly smaller than that in respect of either the medium or small discs whose variances conformed to the calculated, theoretical, value. The values of variance obtained in the experiment were unaffected by colour.

Experiment 2.

Test 1.—A grid of squares, 0·25 inches (0·635 cm.) side, was constructed with harness thread stretched across a rectangular wooden frame. This was used to locate 28,231 sampling points (points of intersection of the thread) within a corresponding rectangular area, in which cards and confetti-like pieces of known area were strewn evenly, in strips, or in certain patterns, without overlapping.

The estimates of cover furnished by the samples were in all cases in close agreement with the actual (known) values.

Test 2.—The distributions of the totals of 100 sets of 200 points found from the data of Test 1, Experiment 2, by (*a*) random, and (*b*) systematic sampling of the pieces spread evenly and in a pattern, were compared with those of the binomial distribution.

The result showed no significant deviations, and it was concluded that systematic sampling remained valid irrespective of the manner in which the sampled area was covered by the card pieces.

Test 3.—Ten samples each of 1,664 and 1,872 points respectively, for each of the cards and different arrangements of the pieces, were taken with (*a*) the distance between points within lines equal to that between lines, (*b*) the distance between points within lines equal to one third of that between lines. The estimates of the means and variances were compared with the expected values of the binomial distribution.

The sample means agreed closely with the known values; the variances in respect of the whole cards were consistently under-estimated; those in respect of the pieces, obtained from the regular sampling procedure, conformed to the expected values, with however a slight tendency to under-estimation; those obtained from the wider spaced lines showed a slight tendency towards over-estimation.

Experiment 3.

A square card of known dimensions was placed in a rectangle, of known area, set out on a laboratory bench. By means of a miniature wheel with one distinctive spoke, a sample of 207 points was obtained in such a way that the distance between points within lines was approximately equal to the distance between lines. By successively shifting the set of sampling lines a short distance to one side within the rectangle, ten separate sets of samples of 207 points each were obtained. The card was then divided successively into 4, 16, 64, 256, 1,024, 4,096 and 16,384 equal squares. With each subdivision of the card ten samples of 207 points each were obtained in the way described.

The sample means again showed close agreement with the actual (known) values, but the variances increased continuously as the size of the individual squares decreased. The values of variance remained, however, consistently lower than the expected value, even after the diagonal length of the smaller squares became less than the distance between the points of the samples.

Since this last result was thought to be due to the fact that the distance between the corresponding lines of each set of samples (the distance through which the set of lines was moved to one side for each new sample) was less than the diagonal lengths of the squares concerned, the data of the samples were grouped to increase in effect the distance between the corresponding lines of the samples. The residual variances found in this way increased in practically all cases.

Experiment 4.

An experiment, similar to Experiment 3, was conducted; but instead of changing the positions of the sampling points, the cards were rearranged in the rectangle after each sample of 200 points was taken. Eight sets of square cards of eight different sizes, respectively, were used and, from these, eight sets of ten samples of 200 points each were obtained.

The sample means furnished were equally reliable in all cases; but the variances showed a progressive increase towards the theoretical value as the size of the cards diminished: the theoretical value was approximated as soon as the diagonal length of the cards became equal to (or less than) the distance between the sampling points.

FIELD EXPERIMENTS.

Experiment I.

In a rectangular area of mixed Karoo vegetation, 132 by 126 yards (120·7 × 115·2 m.), ten samples of 1,804 points each were taken by means of a large wheel apparatus specially constructed for the purpose, and fully described in the paper. For each sample, the distance between the points in the lines was 9·42 feet (2·87 m.), and the distance between lines was 9 feet (2·74 m.). For each successive sample, the set of sampling lines was shifted 0·9 feet (27·4 cm.) to one side, in the same way as in Laboratory Experiment 3. Five different observers, responsible for two samples each, were employed.

The standard deviation in respect of the total cover was significantly smaller than that of the binomial distribution, as in the majority of cases in Laboratory Experiment 3. Of the eight major species examined however, the standard deviations conformed to the theoretical values.

These results were explained by the fact that the vegetation tended to cluster in aggregates (of different species) larger than 0·9 feet (27·4 cm.) diameter (the distance through which the set of sampling lines was moved for each successive sample), whereas the individuals of the constituent species, whose diameters were less than 0·9 feet (27·4 cm.), were distributed more or less independently over the area.

The estimates returned by the five different observers did not differ significantly.

Experiment II.

A rectangular area of mixed Karoo vegetation, 1,272 by 79 yards (1,163·1 × 72·2 m.), was divided into five equal, transverse grids; 25 equidistant lines parallel to the long axis of the rectangle were set out in it. By means of the wheel apparatus 405 points were located in each line. The records in respect of each line within each grid were kept separately. Contiguous grids were grouped in twos, threes, fours and five, and the data of every second, third, fourth and fifth lines, respectively, were grouped to furnish estimates of the means. In this way the distance between selected lines increased progressively while the distance between points within the lines remained constant.

The results, in all cases, were equally reliable: no significant deviations from the weighted means in any of the groups of samples were found.

From the results of all the experiments it was concluded that, subject to certain provisions, systematic samples with points in straight lines furnish direct, reliable, and unbiassed estimates of the basal cover and composition of the vegetation of the areas surveyed, irrespective of the manner in which the components of the vegetation are distributed, and that a simple wheel apparatus, as described in the paper, is a suitable device for obtaining such samples with the minimum of time and effort expended.

Limits of Accuracy.—Graphs showing the limits of error of estimates, at $P = 0{\cdot}05$ and $P = 0{\cdot}01$, for samples of 500 to 4,000 points, and values of cover from 1 to 50 per cent, were constructed from the binomial distribution. From these the approximate level of accuracy required may be read off directly.

Rules of Procedure.—For those who may wish to use the wheel-point method, a set of rules of procedure is formulated.

Example of the Method in Use.—An example of the method in use is presented, and different ways of testing significance are given, including a graph from which the significance, at $P = 0{\cdot}05$, of differences in values may be determined directly.

Uses of the Wheel-point Method.—Applications and limitations of the method in the field are discussed, and the method of comparing the results of surveys of several different areas is stated.

Discussion.—The advantages of the method, including the elimination of certain troublesome concepts and features in ecological survey, the inadequacies of the point-quadrat method, and the apparent confusion of thought in connection with it, are discussed.

Conclusions.—The main conclusions drawn from the work are briefly stated.

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APPENDIX.

For the benefit of field workers who may wish to employ the method of survey in their work, various aspects and contingents that arise in the field, and that are not specifically dealt with in the body of the paper, are considered here.

At the outset it must be clearly stated that when the results of surveys of three or more different areas are to be compared, as when a range of treatments is applied to a number of experimental paddocks (and similarly when the results of several surveys of a single area, made at intervals in time, are to be compared), a heterogeneity test (analysis of variance) must first be applied to the data according to the formula—

(1) $$F = \frac{\frac{Sp_i^2 - Mp_o^2}{M - 1}}{\frac{Sp_iq_i}{N - M}},$$

where—

S = sum of;

M = number of surveys;

n = number of sampling points of each survey;

N = Sn;

$p_i = \frac{\text{No. of strikes}}{n}$ in respect of each survey;

$q_i = 1 - p_i$; and

$p_o = \frac{Sp_i}{M}$.

N.B.—This formula is applicable only when the same number of sampling points is employed in all of the surveys.

The F-table is then entered (consulted) with $n_1 = M - 1$ and $n_2 = N - M$.

(This test must be applied to the data of each species to be compared as well as to the values of total cover, since it may (and does) happen that, whereas the values of total cover may not differ significantly, due to differences in composition of the vegetation, the values in respect of the various species in the different areas, or of the same area at different times, may differ significantly.)

If the value of F is found to be significant from the table, the population (data) is considered to be heterogeneous, and the significance of the difference between any pair of values may then be determined directly from the graphs of Figures 6 to 23; or alternatively the following test may be applied:—

(2) $$t = \frac{p_j - p_k}{\sqrt{\frac{2\,Sp_iq_i}{N - M}}},$$

where—

p_j and p_k are the respective values of the two surveys (areas or paddocks) to be compared;

$N - M$ = number of degrees of freedom;

p_i, q_i, N, M and S are as defined for the first formula, and the number of sampling points employed is the same in all of the surveys.

If the value of F in the heterogeneity test does not show significance, the population is considered to be homogeneous, and further comparison is invalid.

Where *different numbers of sampling points* are employed in the surveys, the formula for testing for heterogeneity becomes—

$$(3) \qquad F = \frac{\dfrac{Sn_ip_i^2 - Np_o^2}{M - 1}}{\dfrac{Sn_ip_iq_i}{N - M}},$$

where—

n_i = number of points in each separate survey;

$N = Sn_i$;

$p_i = \dfrac{\text{No. of Strikes}}{n_i}$;

$q_i = 1 - p_i$;

$p_o = \dfrac{Sn_ip_i}{Sn_i}$;

and S, M are as defined for the first formula.

The F-table is entered with $n_1 = M - 1$ and $n_2 = N - M$.

If the value of F is found to be significant, the significance of the difference between any pair of values may then be tested by means of the formula—

$$(4)\ t = \frac{p_j - p_k}{\sqrt{\left(\dfrac{1}{n_j} + \dfrac{1}{n_k}\right)\dfrac{Sn_ip_iq_i}{N - M}}}$$

where p_j and p_k are as defined for the second formula, n_j and n_k are the respective numbers of sampling points employed in the two surveys to be compared, and the other symbols are as defined in the third formula. The number of degrees of freedom is $N - M$.

N.B.—The graphs of Figures 6 to 23 may not legitimately be used in cases in which different numbers of sampling points are employed.

Should the field worker prefer to use the graphs supplied with this memoir and decide therefore to employ the same number of points in all comparable surveys, irrespective of the sizes of the areas surveyed, he may adopt the following procedure:—

Suppose a set of 6 paddocks of 5, 10, 20, 30, 40 and 50 morgen (4·3, 8·6 17·1, 25·7, 34·3, 42·8 hectares), respectively, are to be surveyed, that it is not advisable to extend the distances between sampling lines (traverses) to more than 45 feet (13·72 m.), and that the number of sampling points required per survey (paddock) is 2,000. In the case of the first two paddocks no difficulty will be presented: with points 9·42 feet (2·87 m.) apart in the lines (when one marked spoke of the wheel is used and the points furnished by every revolution of the wheel recorded) the distance between sampling lines will be 22·5 feet (6·86 m.) and 45 feet (13·72 m.) respectively.

In the case of the third paddock the points furnished by every second revolution of the wheel may be recorded to provide points 18·84 feet (5·74 m.) apart in the lines, and the distance between sampling lines will then remain at 45 feet (13·72 m.).

Similarly in paddocks 4, 5 and 6 the points furnished by every third, fourth and fifth revolution of the wheel, respectively, may be recorded to provide in each case 2,000 point samples, with sampling lines 45 feet (13·72 m.) apart. (The procedure to be adopted in cases of intermediate areas is readily determined.)

In the case of the last paddock, the distance between the sampling points in the lines will also be approximately 45 feet (13·72 m.), and the ideal systematic sample will once more be attained.

Beyond this stage the distance between the sampling lines could once more be extended. In intensive research, however, in which a complete survey of the whole paddock is required, paddocks as large as 50 morgen (42·8 hectares) are seldom employed; even 20 morgen (17·1 hectares) is a large paddock in such work.

Should it become necessary to resort to the procedure described, it will be found of great help to attach some mechanical device to the wheel whereby a warning bell is struck at every second, third, fourth or fifth revolution of the marked spoke, as required.

In conclusion it should be pointed out that though the analysis of the data is somewhat facilitated by keeping the number of sampling points constant for all surveys, the sacrifice of point records when, in large areas, every second, third, fourth or fifth revolution of the wheel is used to furnish a point sample, has its disadvantages in that it is usually necessary to compare the successive surveys of each paddock also in time, and for this purpose the more accurate sample furnished by a greater number of point records (which enables the detection of smaller differences in values) has a distinct advantage, especially where rare, but important, species are concerned.

Every field worker will have to decide for himself which procedure to follow.

FIG. 6.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 0–1 per cent. (500 points per paddock.)

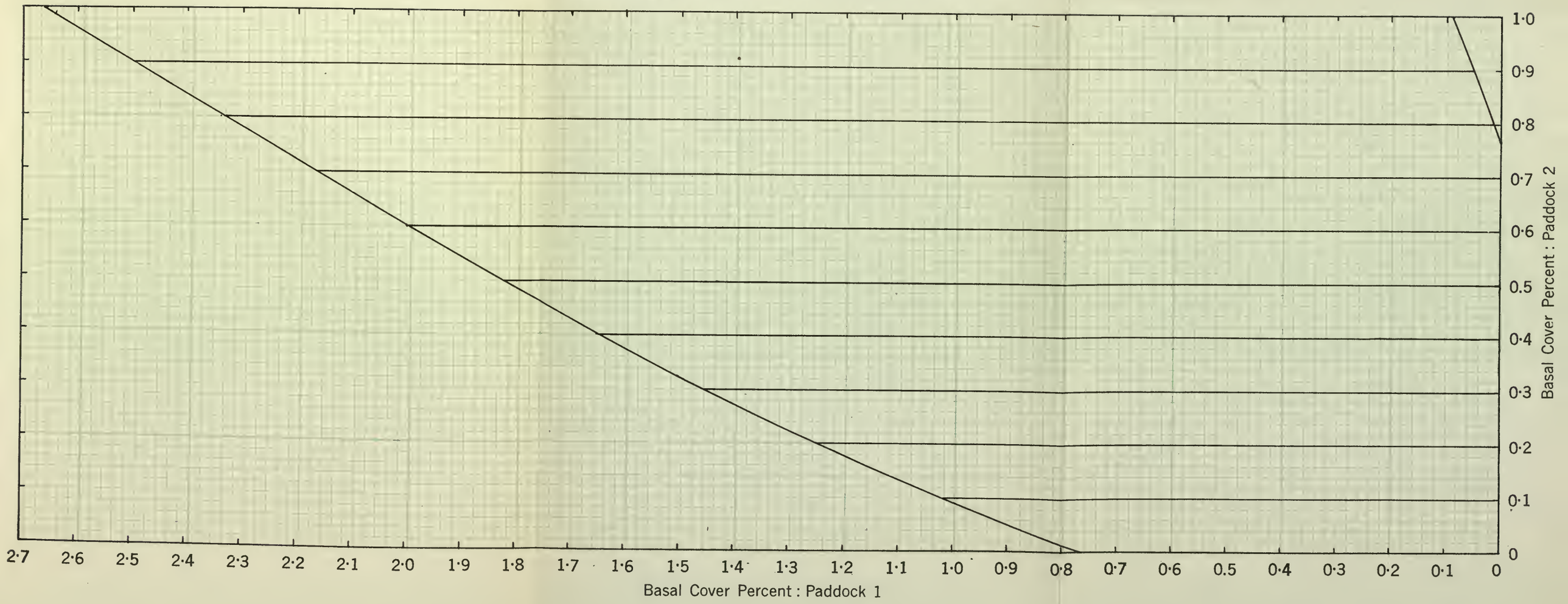


FIG. 7.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 1–10 per cent. (500 points per paddock.)

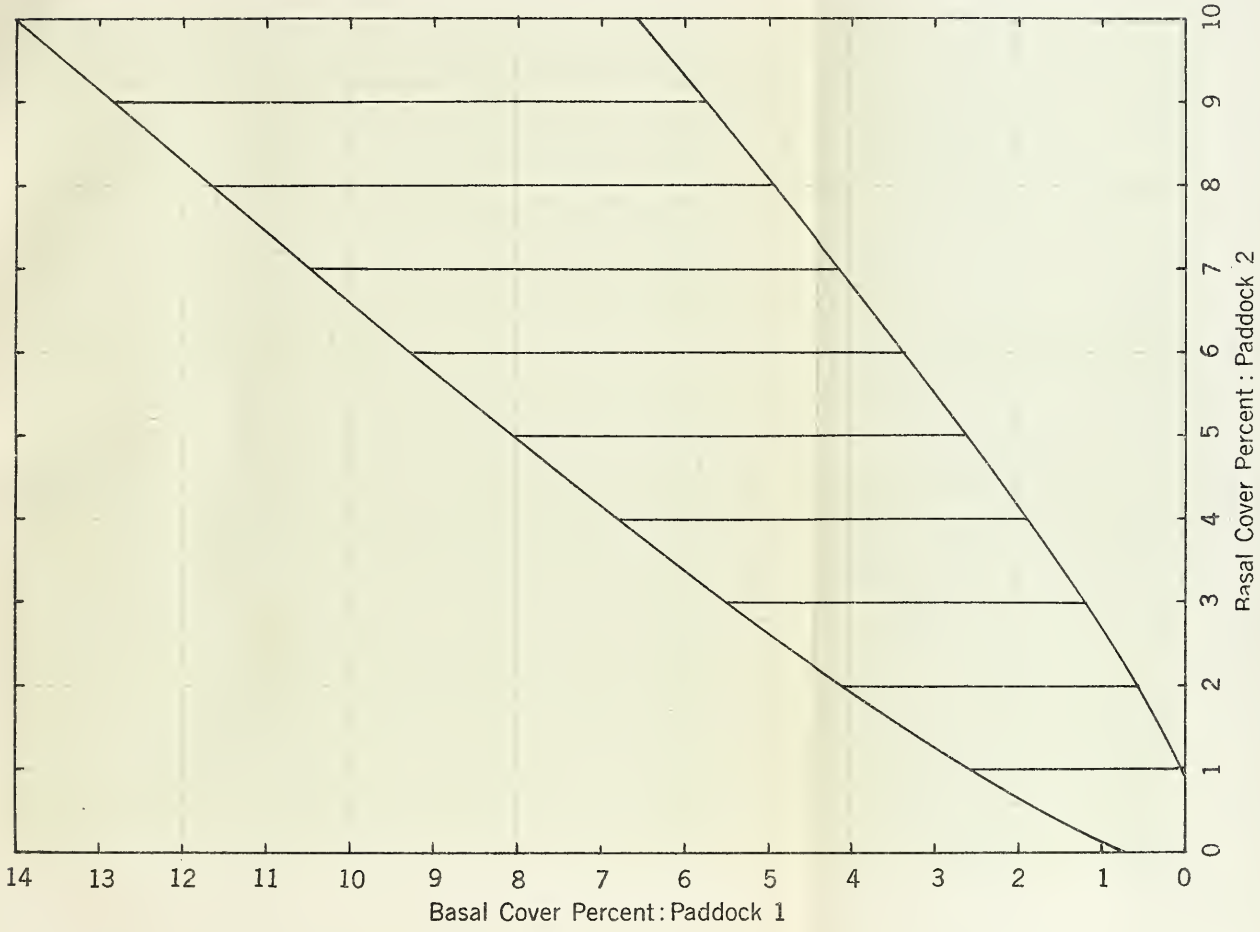


FIG. 8.—Determination of significance ($P = 0.05$) of differences in values of two paddocks ranging from 10–50 per cent. (500 points per paddock.)

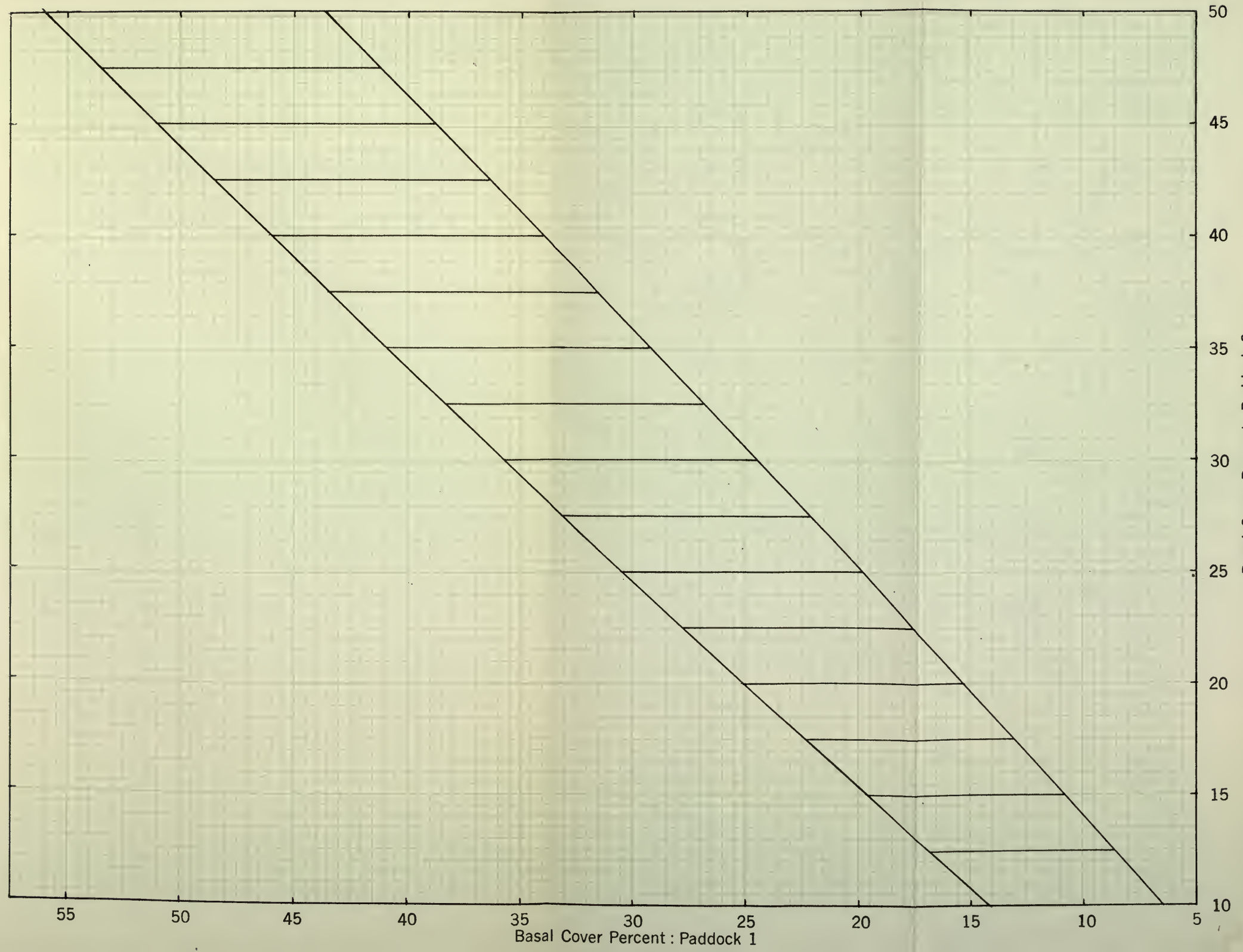


FIG. 9.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 0–1 per cent. (1,000 points per paddock.)

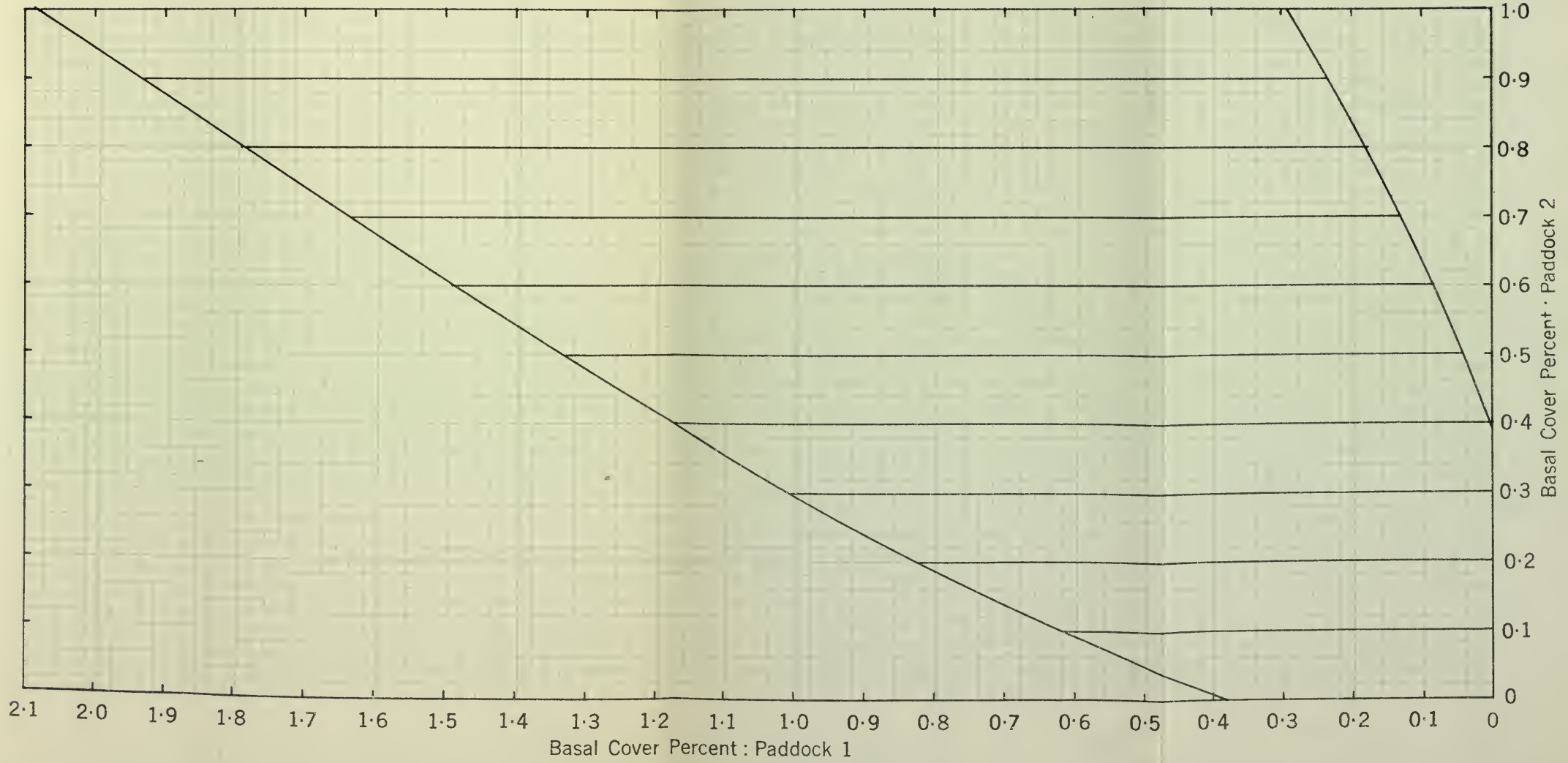


FIG. 10.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 1–10 percent. (1,000 points per paddock.)

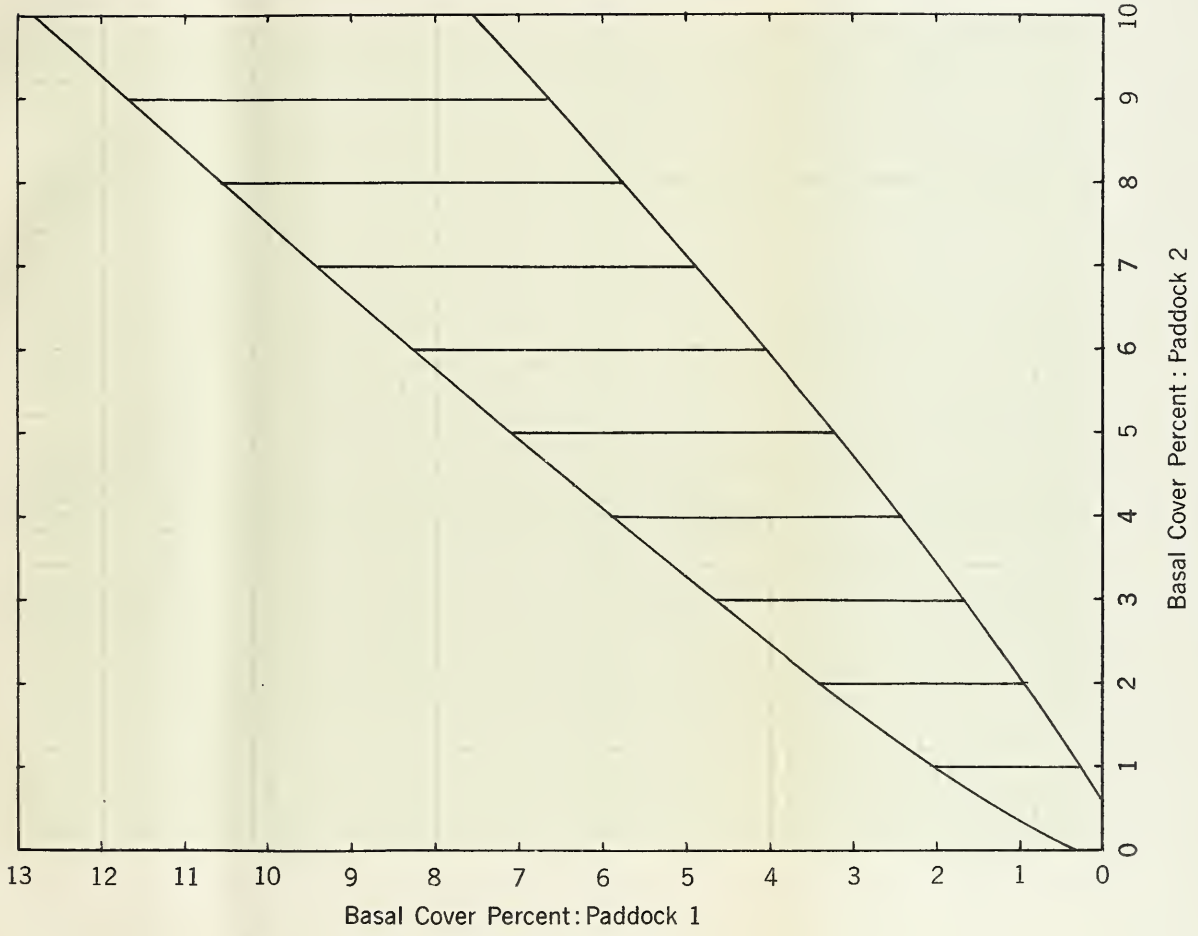


FIG. 11.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 10–50 per cent. (1,000 points per paddock.)

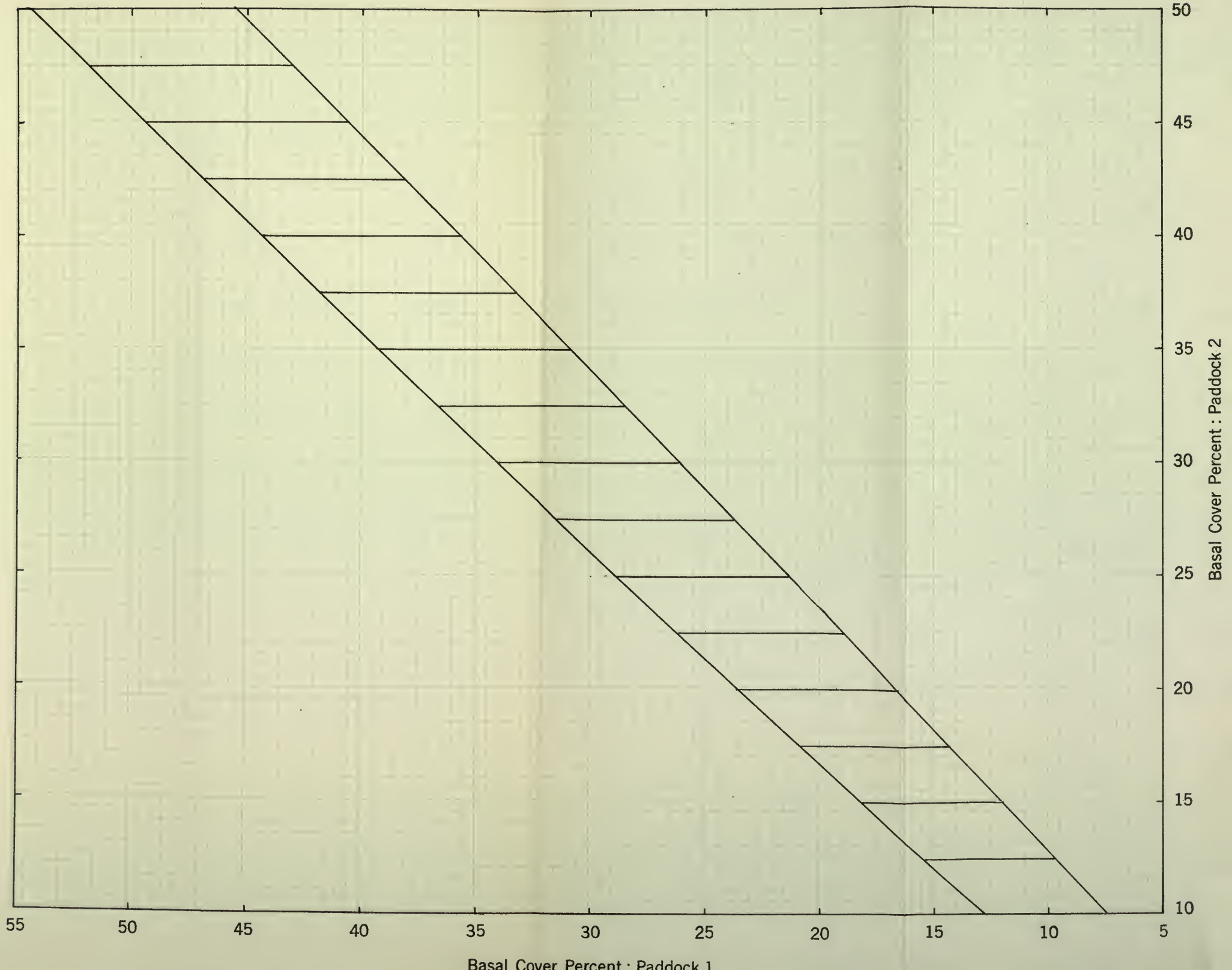


FIG. 12.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 0–1 per cent. (1,500 points per paddock.)

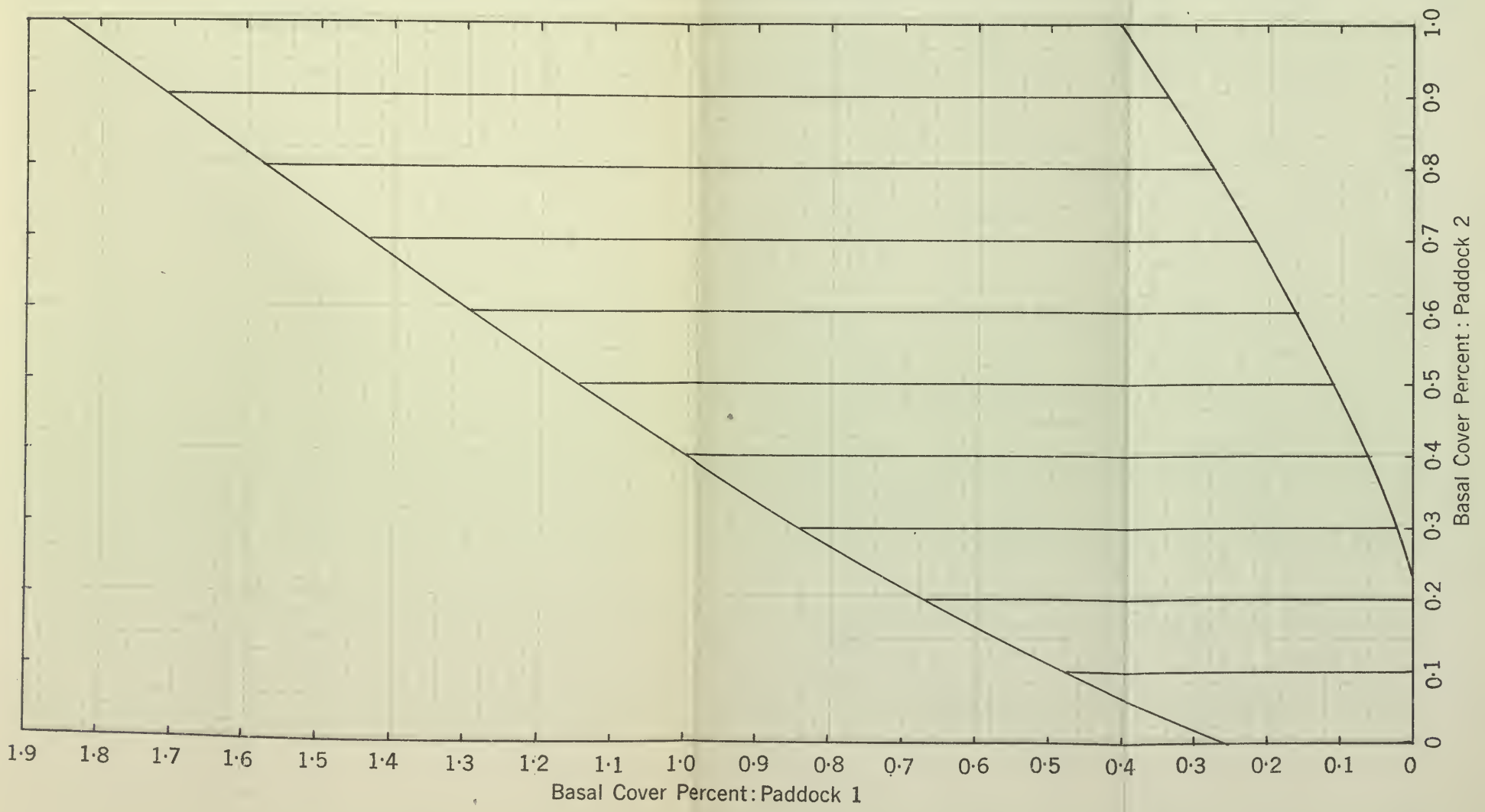


FIG. 13.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 1–10 per cent. (1,500 points per paddock.)

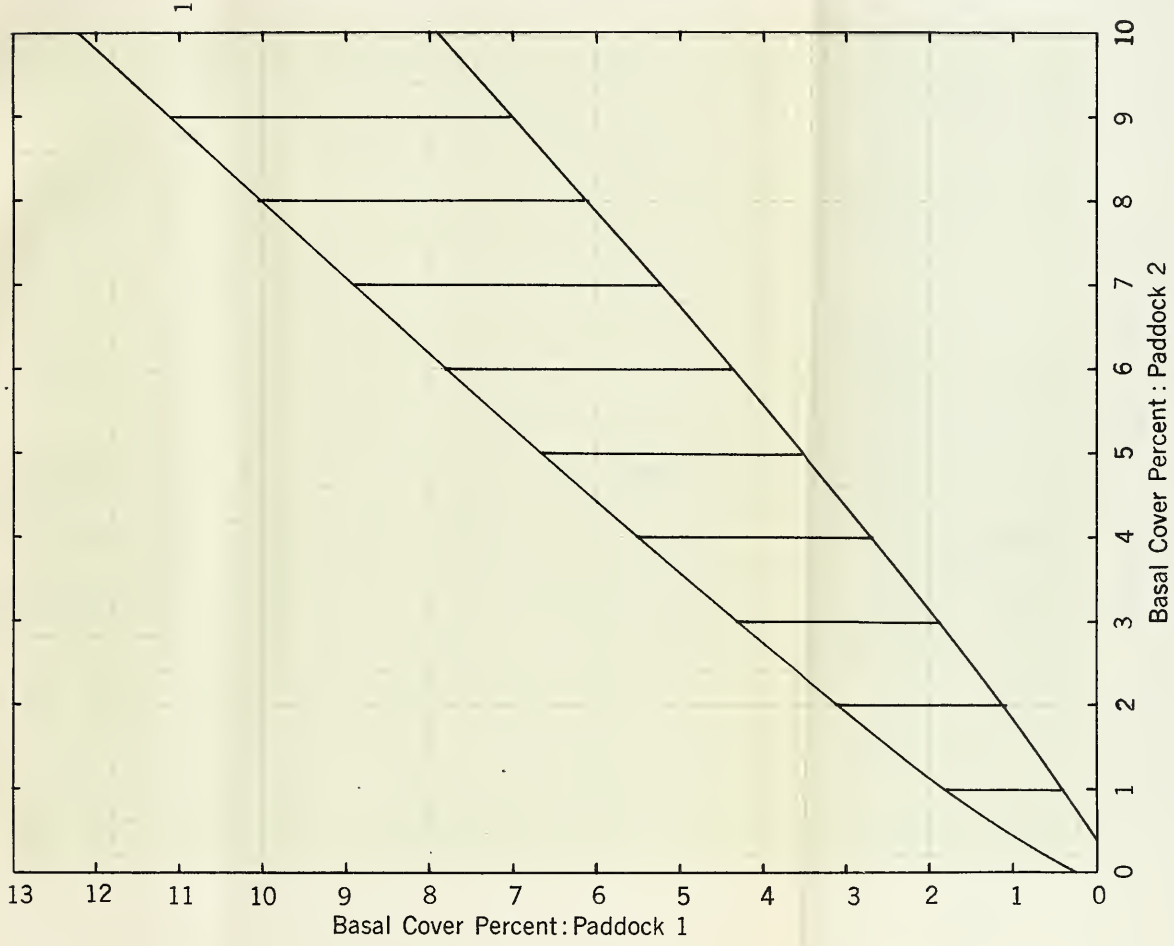


FIG. 14.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 10–50 per cent. (1,500 points per paddock.)

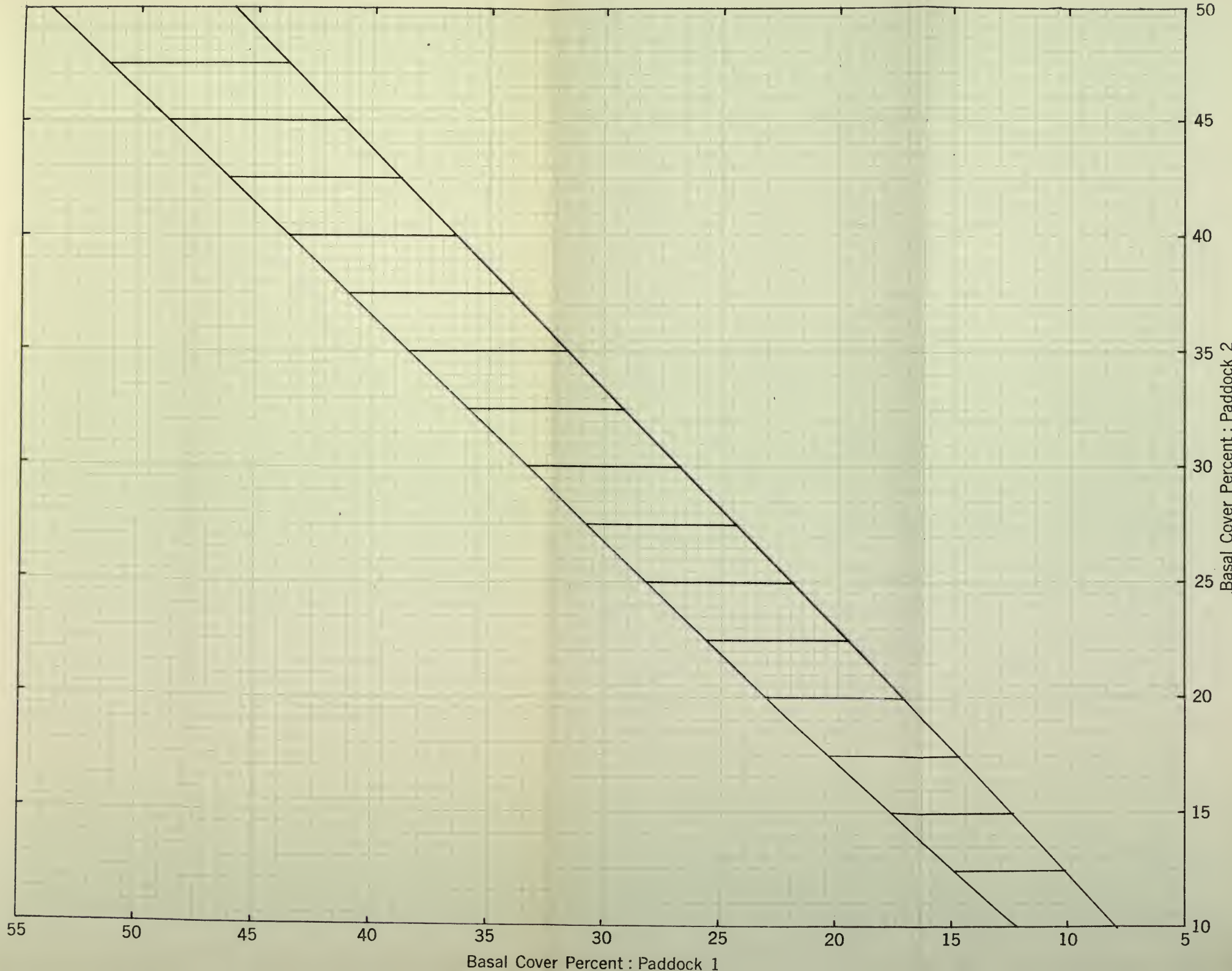


FIG. 15.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 0–1 per cent. (2,000 points per paddock.)

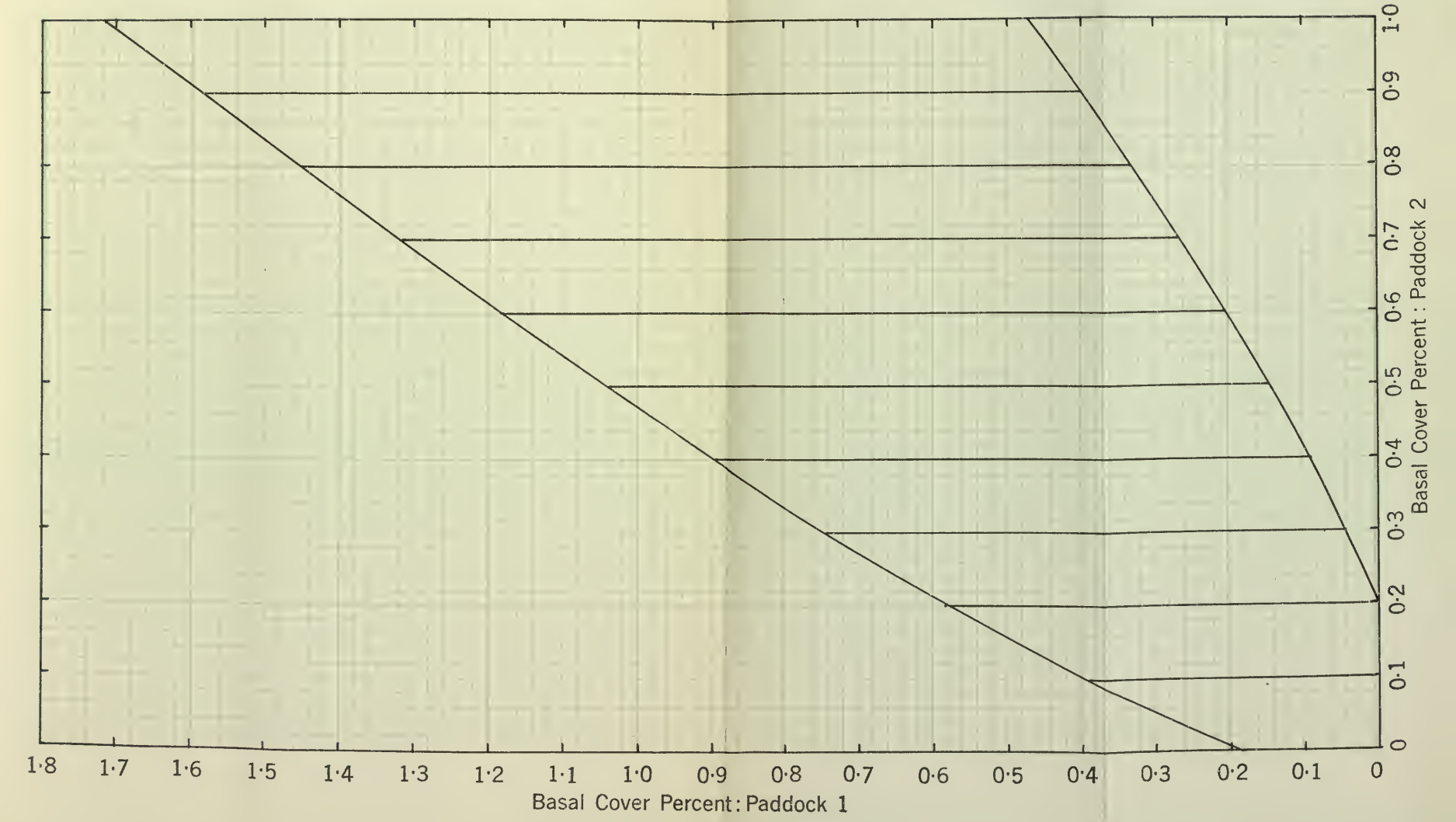


FIG. 16.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 1–10 per cent.) (2,000 points per paddock.)

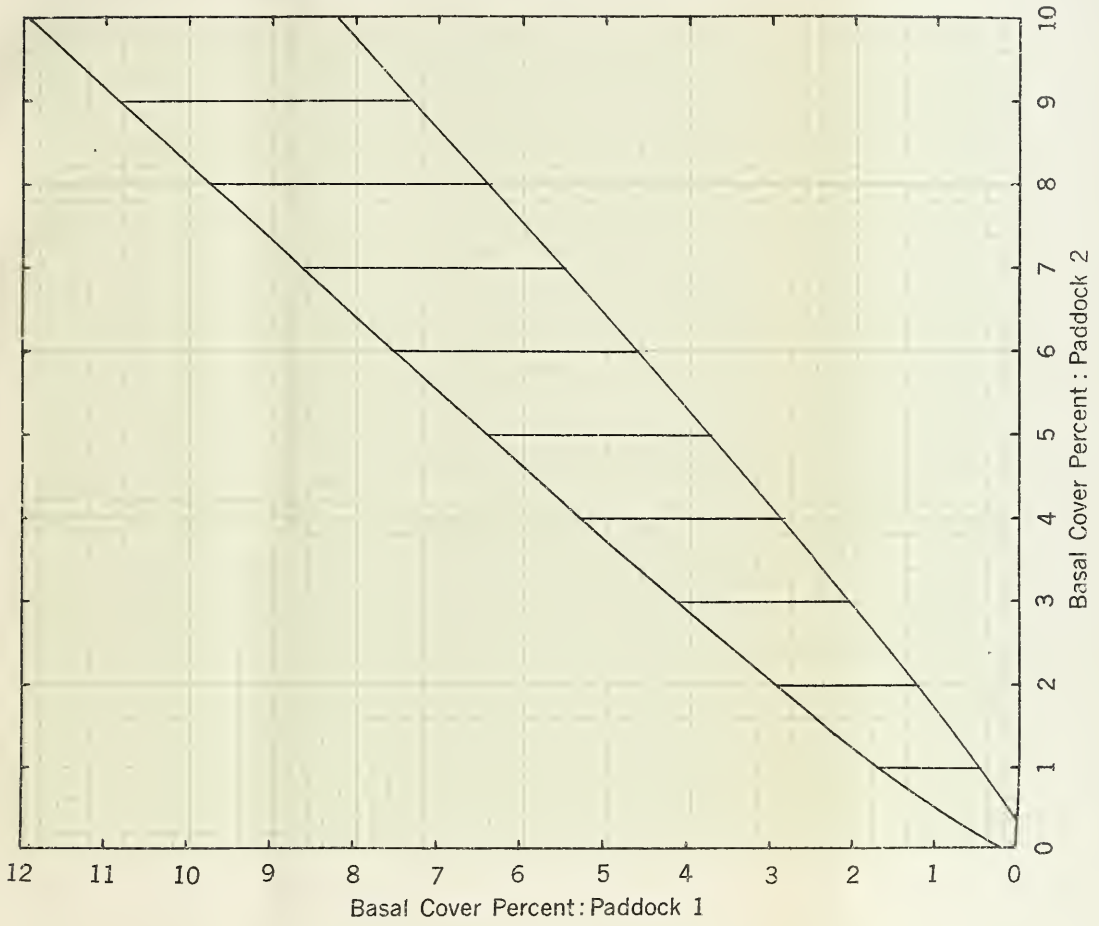


FIG. 17.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 10–50 per cent. (2,000 points per paddock.)

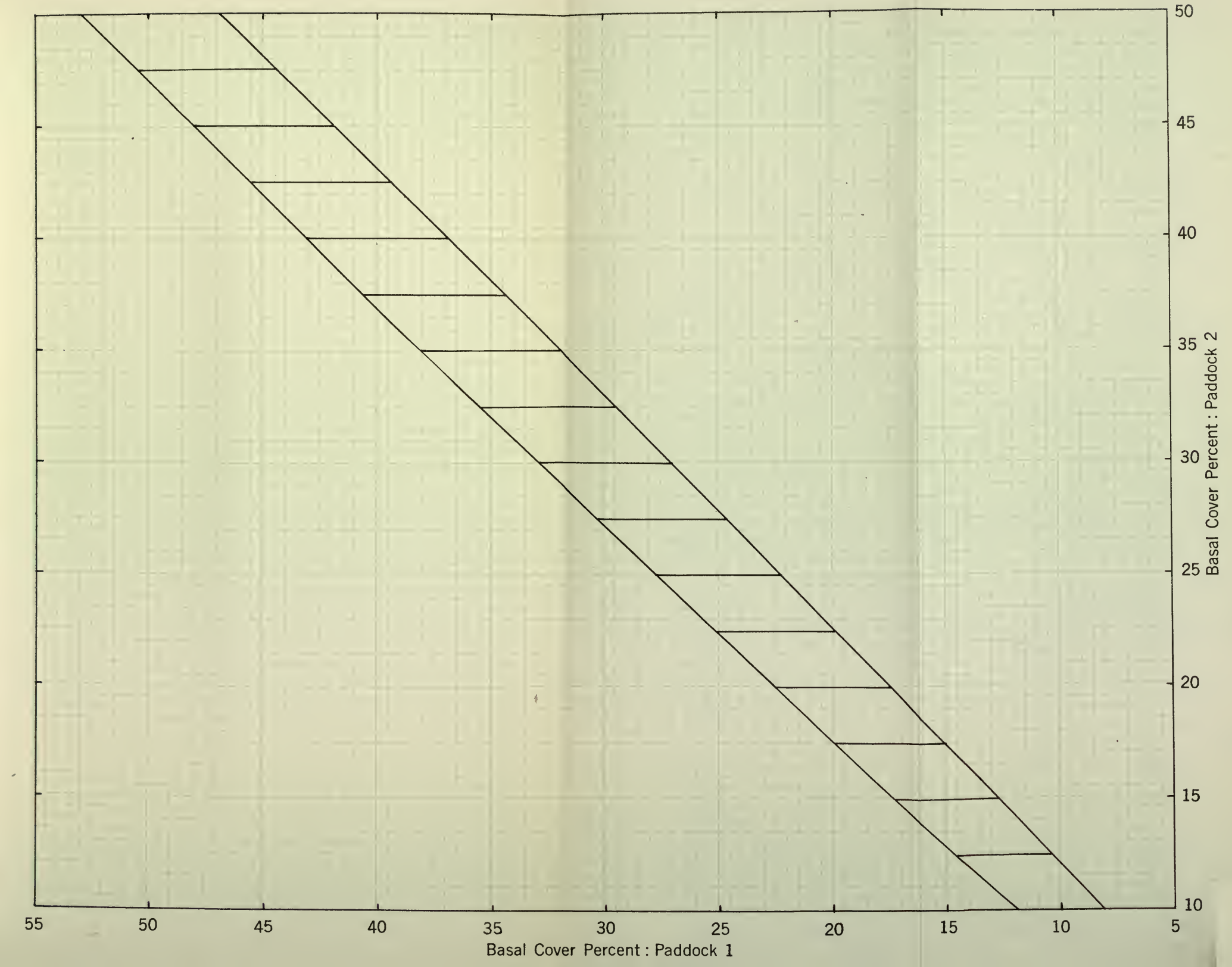


FIG. 18.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 0–1 per cent. (3,000 points per paddock.)

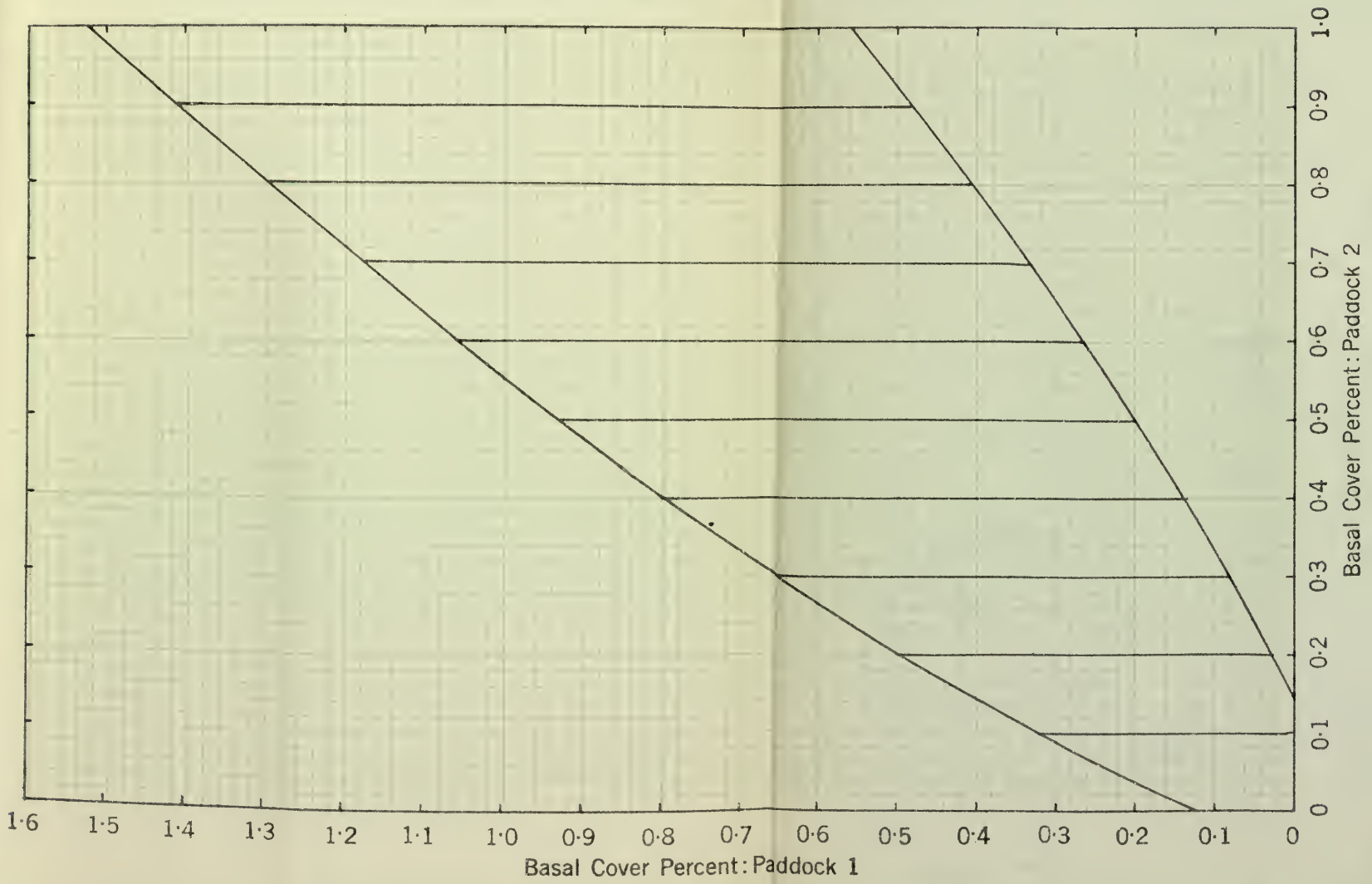


FIG. 19.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 1–10 per cent. (3,000 points per paddock.)

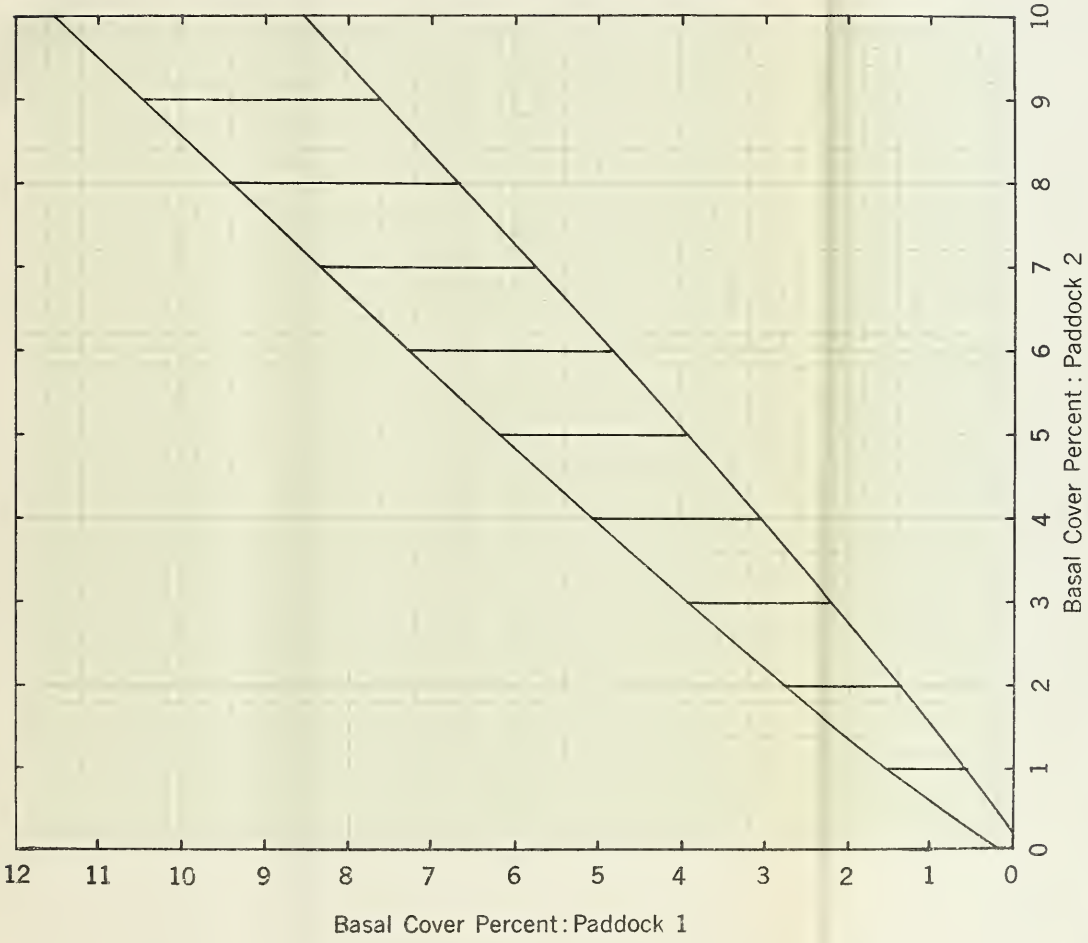


FIG. 20.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 10–50 per cent. (3,000 points per paddock.)

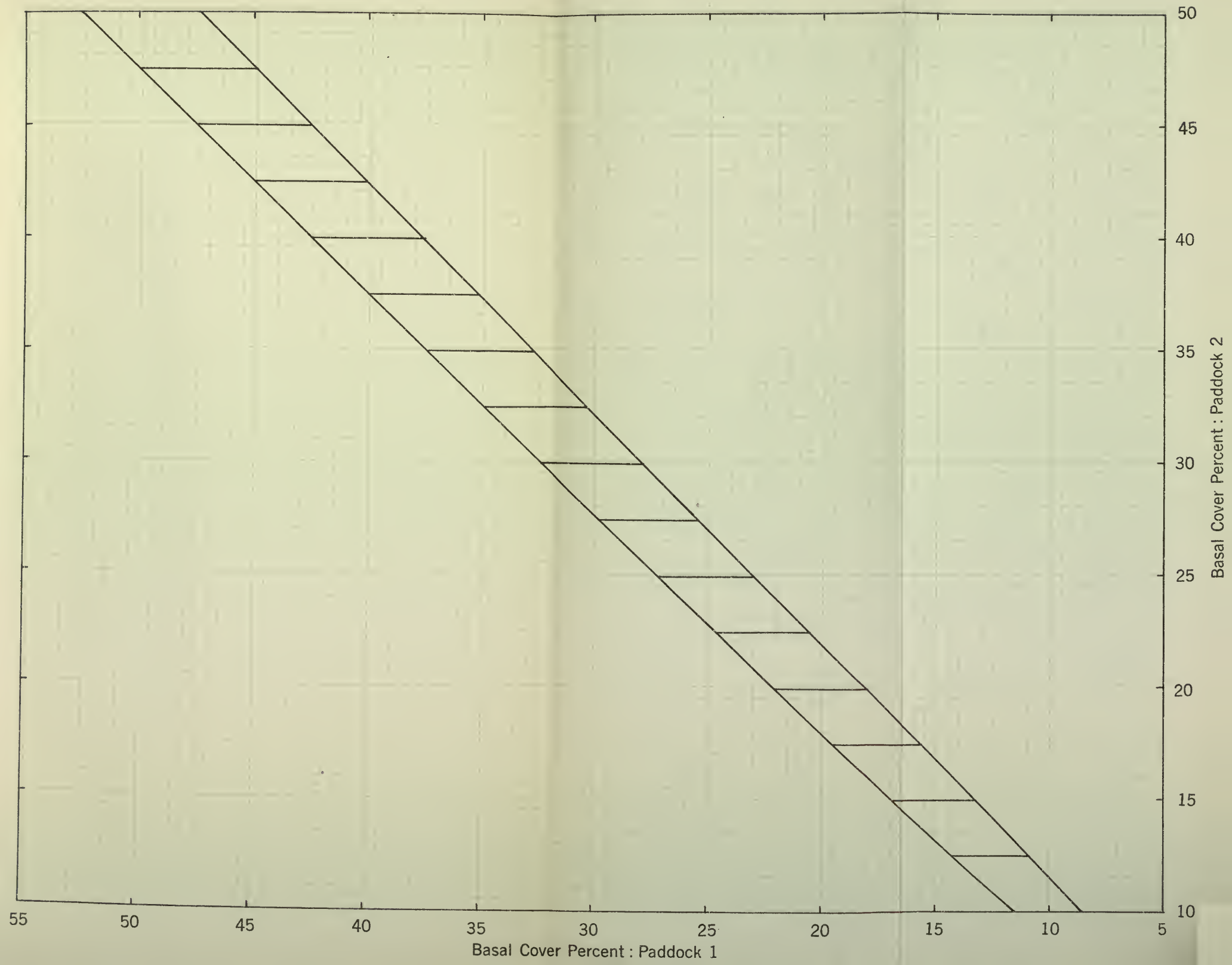


FIG. 21.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 0–1 per cent. (4,000 points per paddock.)

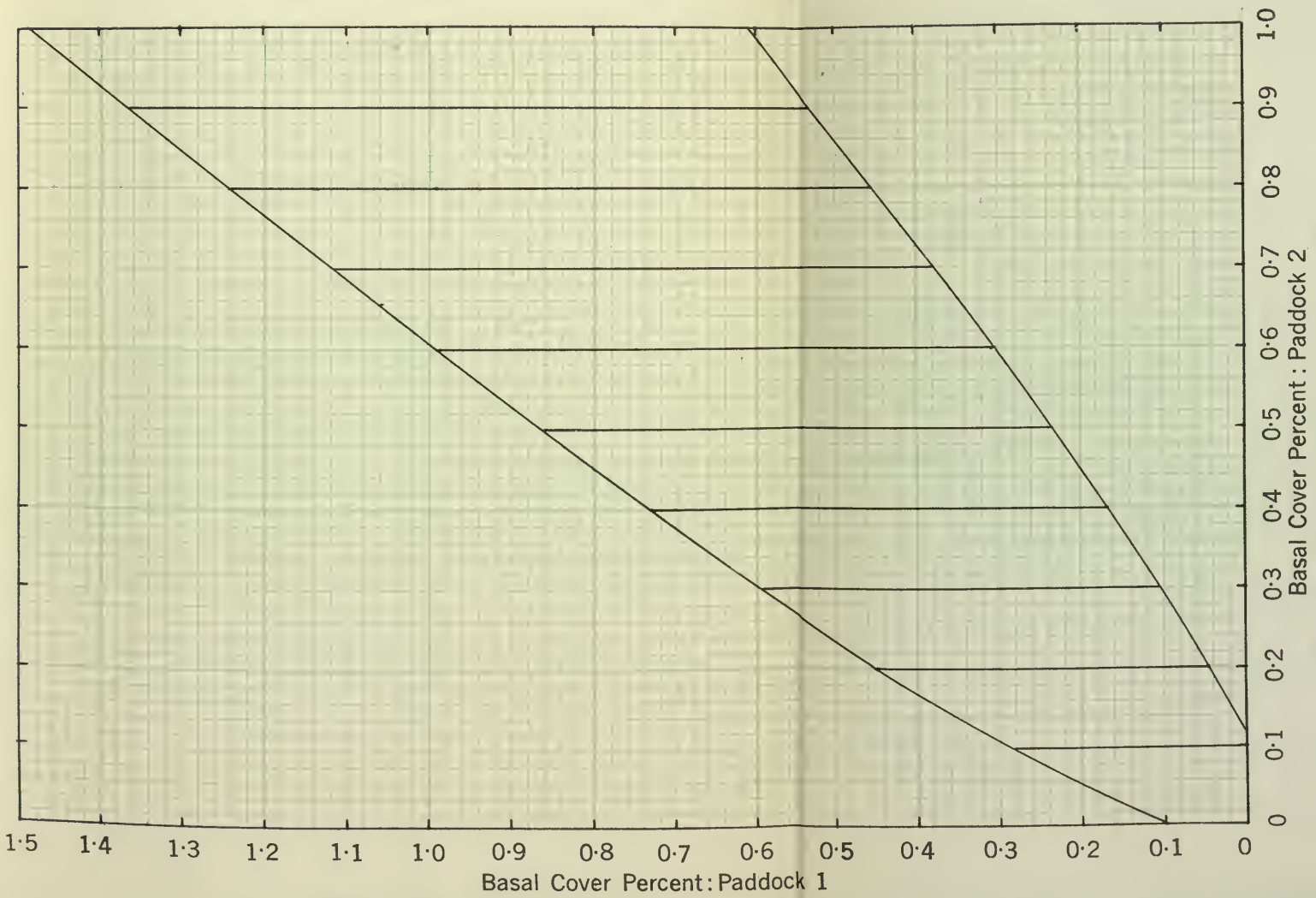


FIG. 22.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 1–10 per cent. (4,000 points per paddock.)

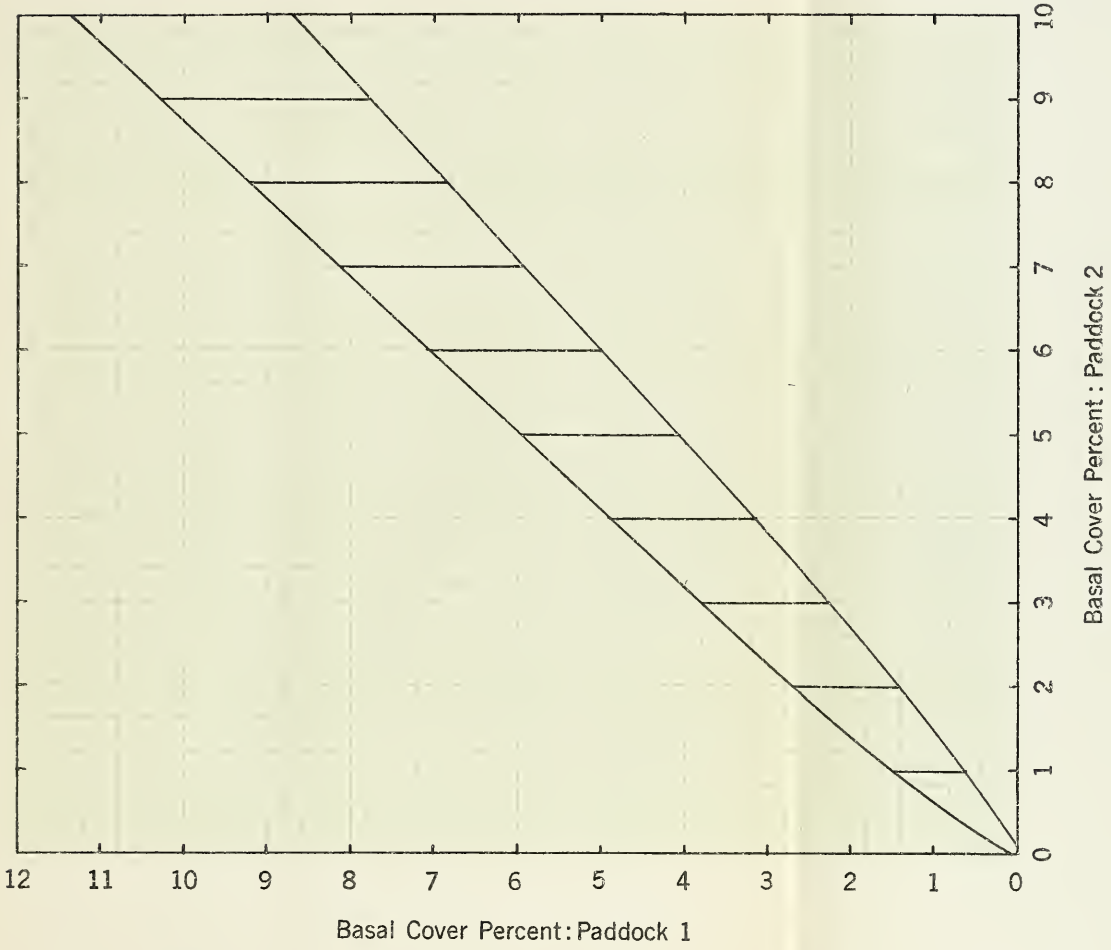
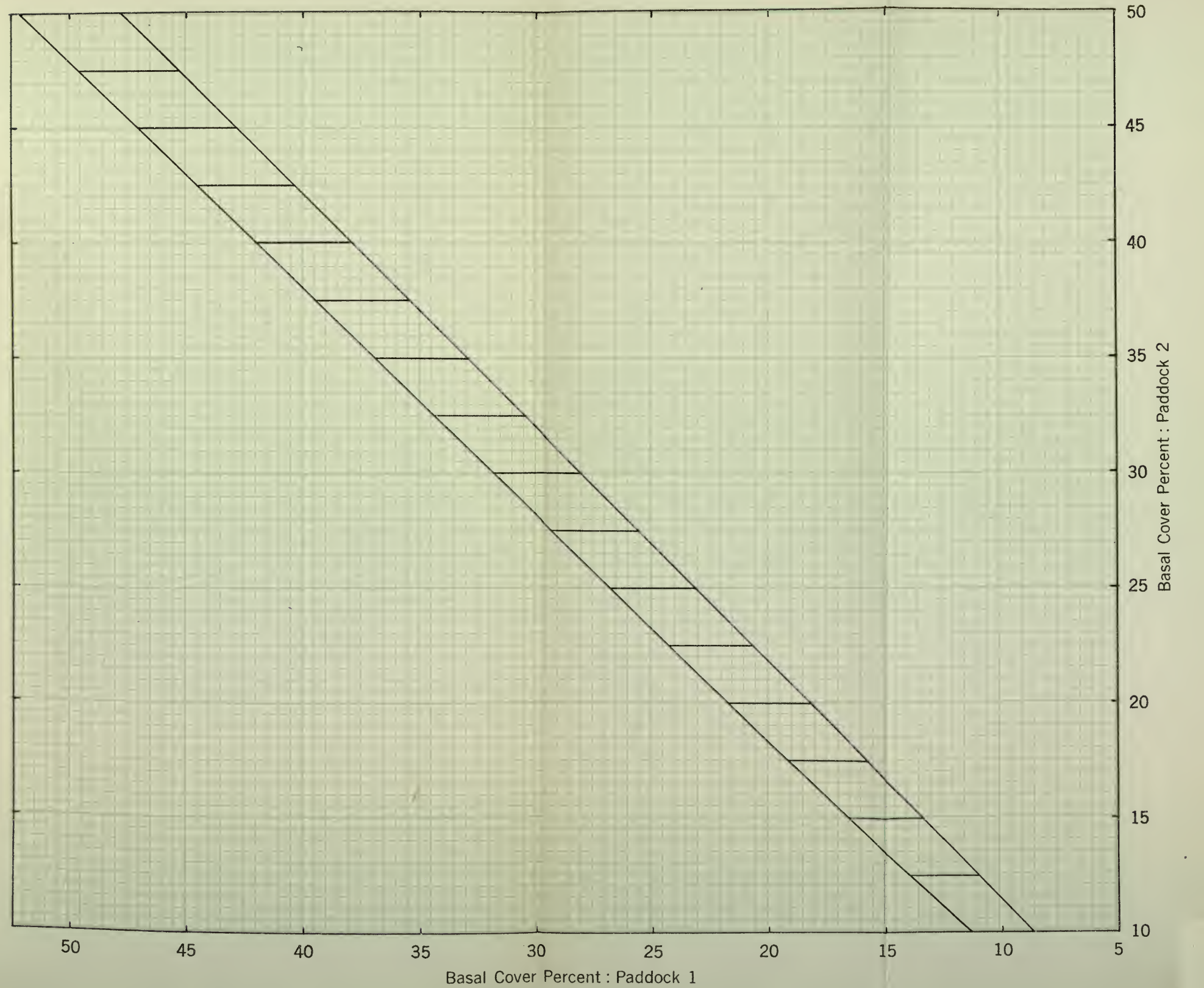


FIG. 23.—Determination of significance (P = 0·05) of differences in values of two paddocks ranging from 10–50 per cent. (4,000 points per paddock.)



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Some Plants Used by the Bushmen in Obtaining Food and Water

BY

R. STORY, D.Sc.

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1958

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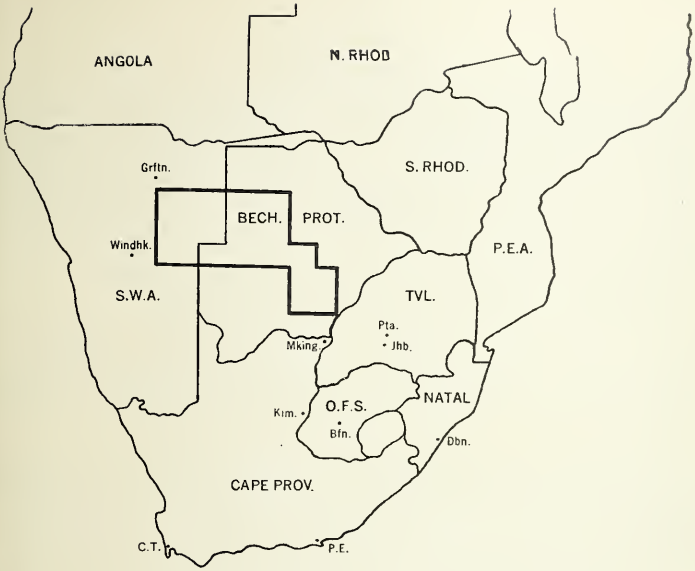

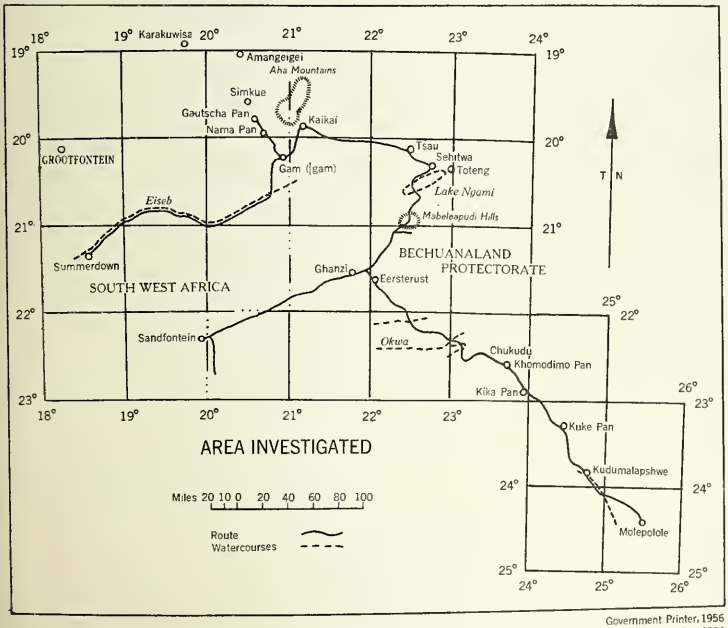

Government Printer, 1956
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GENERAL AND DETAILED MAPS
OF THE AREA COVERED IN THIS STUDY.

FOREWORD.

The Kalahari is not a sandy desert in the sense that it is devoid of vegetation; it is the absence of surface water which makes the region such a hazard to human habitation. It is the last refuge of the Bushman. Primitive though he is, he survived in this inhospitable environment owing to his acute powers of perception and his fine appreciation of the gifts of nature. He is a skilled hunter with his bow and arrow and has an intimate knowledge of the natural resources of food and water. Dr. Story compliments him by saying that his knowledge was usually imparted cheerfully and with humour and " always with intelligence ".

The Division of Botany was grateful to accept the invitation for Dr. Story to accompany the Harvard-Smithsonian-Peabody expedition of 1955. This was the fifth expedition of its kind and had as its objective the further documentation of the way of life of the Bushman. Dr. Story's assignment was to investigate the plants used by them in obtaining food and water.

It is inevitable that, with the advance of civilisation, the remnants of this interesting race will lose its intimate contact with nature and in the end its very identity. Wishing to complete their records before this happens the Harvard-Smithsonian-Peabody organisation, is, as we go to press, returning on yet another expedition. The Division of Botany is glad of this opportunity to continue the collection of data on the plants of economic importance to the Bushmen in the Kalahari.

The balance in nature between supply and demand is of endless interest to the ecologist. In times of plenty—when vegetation is abundant —the animal population increases: in times of poverty—when the vegetation is reduced by the prevailing climatic conditions—the animal population is reduced by the effects of hunger and thirst. So it is with the primitive human, who is dependent for his survival on the animal and plant life which surrounds him. Overpopulation at any time spells destruction for him at a later date. It is obvious too, that primitive man must have had a strong influence on the distribution and density of edible wild plants. Some will have become more widespread and others less numerous. More and more examples of rare species among the tuberous rooted *Asclepiadaceae* have come to light during the botanical exploration of southern Africa. It is felt that the edibility of these and some other tuberous rooted plants, in a large measure, accounts for their sparse distribution.

Dr. Story's observations support this view, and many other interesting facts are recorded in his preliminary report on the vegetable aspect of the Bushman's diet.

R. A. Dyer,
Chief: Division of Botany and
Director of Botanical Survey.

Pretoria,
October, 1957.

INTRODUCTION.

Early in 1955 the Chief of the Union Government Division of Botany received a request through the British Museum for a botanist to accompany the Harvard-Smithsonian-Peabody expedition, which in the winter of that year was to make a study of the Bushmen of the Bechuanaland Protectorate and South West Africa. The duties of the botanist would be to investigate and report upon the plants used by the Bushmen in obtaining food and drink, and this task was assigned to me in my capacity as one of the Botanical Survey Officers of the Division of Botany.

I joined the expedition on 10th June at Molepolole, after it had been some weeks in the field, and we thereafter travelled along the route shown on the map, reaching Windhoek on 2nd September.

There were two main areas of study, one in the country south of Ghanzi and the other north of Ghanzi. The southern area, part of the Kalahari Desert, was remarkably uniform in every way. The surface was deep loose sand, gently undulating and with occasional shallow depressions of firm dark soil known as pans, which collect a little water after rain. We did not see a hill after leaving Molepolole until the Ghanzi area was reached, nor a stone, except for shelves of limestone in some of the pans. There was no permanent water in the 300 miles between Kudumalapshwe and the Ghanzi farms, but Khungwane waterhole and Khomodimo Pan had not yet dried up. Khungwane held one or two thousand gallons and Khomodimo contained a pond about thirty yards across and a foot or so deep. It provided a home, rather unexpectedly, for a coot (*Fulica cristata*) and a water-scorpion (one of the *Nepidae*). There are no records of the central Kalahari rainfall, but it would be between 18·5 and 19·6 inches, which are the mean annual figures for Ghanzi and Molepolole respectively. In spite of this low rainfall, and although we were there in the dry season, we found that the sand a few inches below the surface and down to at least three feet was damp enough to retain its form when squeezed in the hand. One specimen of a species of Breviceps was found in the sand, a small burrowing frog which does not swim or jump and which passes through its tadpole stage in a mass of frothy material which surrounds the eggs. The commonest animals were the rodents whose burrows and tracks were in thousands along our route. The game included gemsbok, springbok, hartebees, eland, blue wildebees, giraffe and smaller antelopes and hares. Of the carnivora, lions, leopards, wild dogs, jackals and hyaenas were present. Ostriches and bustards were seen and occasional small birds of various species, but birds were on the whole poorly represented. The vegetation was mainly grassland, usually about four feet tall and mixed with many shrubs a little taller. Trees were seldom absent for more than a few miles at a stretch, and were scattered to form a parkland or in belts thick enough to hamper the progress of our lorries through them.

The northern area was much more varied, with the undulations sometimes forming distinct rises and dales. Hills, however, were still absent, although there were occasional outcrops of limestone and other rock. The soils were for the most part fairly firm, but sandy nevertheless, and damp below the surface. From time to time we crossed zones of purer loose sand, slightly raised above the surrounding country and known as dunes. A number of permanent waterholes, groups of large pans and a rainfall estimated to be about 20 inches a year (Department of Transport 1953) made this area better watered than the Kalahari, and better wooded.

There were more species of grass, and, particularly on the dunes, more of trees and shrubs. The fauna was also richer for there were buffalo and elephant and many waterfowl in addition to the animals found in the Kalahari.

The Bushman languages represented in this paper are classified according to Bleek's *Comparative Vocabularies of Bushman Languages* (1929). They are !hɔ̃:, the closely interrelated ǁganakwe, ǀgikwe and Naron, and Auen (see also Bleek, 1928: 60-64).

!hɔ̃: is a member of the southern group, in which the lip click is found, and a dialect of what Bleek calls ǀnuǁen, S6 in her system of classification. Bleek's spelling is !kɔ̃:, but I heard the click aspirated. It is spoken in the neighbourhood of Lehututu, which is 150 miles south of Ghanzi.

ǁganakwe is spoken to the east of Ghanzi, and has been studied by Maingard (1957).

The centre of the ǀgikwe language appears to be in the country to the south-east of Ghanzi. It is a member of Bleek's Central group, closely allied to Naron and easily understood by Naron speakers although many words are different. A curious feature of the phonetics is the occurrence of the ejective lateral explosive followed immediately by the velar glottal affricate (see Cole, 1955: 23 and Beach 1938: 222-223). The first sound is not mentioned in any papers that I have seen on the Bushman languages.

Naron is Bleek's C2. There is an error which is liable to confuse one on page 3 of her publication, where the languages of the Naron and Masarwa of Tati have been transposed. Naron should be under C2 and the Masarwa language under C1. A grammatical sketch of Naron is given in Bleek's paper of 1928.

Auen, Bleek's N1, is the eastern form of the !khũ linguistic group and is spoken round Gautscha Pan. It was studied by Maingard when he was a member of this same expedition and an account of it is given in his paper of 1957. In this paper I refer to it as Eastern !khũ.

The work done in the Kalahari was done through interpreters, and much of that in the northern area likewise, except towards the end of the expedition when through closer contact with the Bushmen for a longer time than in the south, I was able to acquire a smattering of the Eastern !khũ language, enough to ask straightforward questions and to understand straightforward replies. The phonetics of the Bushman languages are a study in themselves, and I do not claim that my spellings and indications of the tones are exact. In the orthography I have followed Bleek (1929) with the following exceptions:—

1. I have placed the n first when it is combined with a click. It has been the convention to place the n after the click in the written Khoisan languages, the argument being that the n and the click are pronounced simultaneously (Meinhof, 1909: 5). To my ear the n is the first sound in the combination.
2. Bleek does not mention the voiced h, which sometimes follows a nasalised click. I have accordingly followed Doke (1936: 448) and used the symbol ɦ.

For easy reference, the symbols I have used are listed at the end of this introductory chapter.

As the spellings of the Bushman names on my herbarium specimens are from field notes, they are often different from the spellings given in this paper, which was done after I had had the opportunity of consulting the authors I have mentioned. It will be noticed that many of the plants do not have the full set of Bushman names. The main reason is that we were not in contact with the Eastern !khũ speakers until we had passed Ghanzi, and lost contact successively with the |gikwe, ||ganakwe and !hɔ̃: speakers as the expedition drew to a close. Other reasons are that my field notes were sometimes inadequate, that I forgot to ask, and that some plants appeared restricted to certain areas and were not known to all the groups of Bushmen.

As the expedition was during the winter when most of the plants were in poor condition, very little photography was done in the field. Most of the photographs are from plants which were sent back to Pretoria and cultivated there, or from plants which grow naturally in the Transvaal. In this paper the plants and photographs are arranged according to de Dalla Torre and Harms (1900-1907). Specimen numbers are in brackets.

There is little doubt that the plants discussed here represent only a fraction of those used, for we covered a very small part of the area over which the Bushmen range, and this when probably most of the annuals were dead, when some foods were out of season and when the above ground parts of many bulbous and tuberous plants had withered and disappeared so that the plants themselves could not be found.

Because of poor yield, poor quality, difficulty in harvesting or lack of flavour, not many of the Bushman food plants would be worth cultivating in their present form for the use of civilised people, but they offer a large field to the plant breeder. The most promising have been noted accordingly in the text.

There were few bones around the Bushman encampments, but this does not necessarily mean that there is a scarcity of meat in their diet, for the bones might have been removed by porcupines (Alexander, 1956; Dart, 1957) or eaten by hyaenas. A more reliable indication was the scantiness of the Bushmen's skin coverings. There are sharp frosts in the Kalahari and sometimes bitter winds, and one may argue that the Bushmen would provide themselves with sufficient skins if they had a regular supply of meat, although admittedly they eat skins after charring them on the coals and pounding them in a mortar. Vegetable refuse from former meals and fresh vegetable food, however, were found at all the Bushman encampments, and additional gatherings were the permanent chore of the women and children and of the men to a lesser degree. The insanitary condition of the surroundings also provided unmistakable evidence that the bulk of their food was of vegetable origin.

Their knowledge of field botany was astonishingly good. It has to be, otherwise they would have no chance of survival in their arid country. Fragments of stem, dead leaves, and other small clues of this nature, after being unerringly identified, were all the Bushmen needed to find many of the storage organs they were seeking. Differences which escaped me would enable them to distinguish between edible and harmful plants, and they had a thorough knowledge of the areas and habitats in which their food plants grew. They must have an influence on the distribution of plants,

spreading some like the Grewias and the melons whose seeds pass through the alimentary canal apparently unharmed and reducing others like the Eulophias and Vignas which have edible underground storage organs. It is perhaps significant that, with two exceptions, the edible members of the family Asclepiadaceae were rarely found. In this paper there are 11, from Raphionacme to Fockea inclusive—nearly all important food plants with underground storage organs. The two commoner exceptions were *Sarcostemma viminale* which is sometimes poisonous and *Pentarrhinum insipidum* which has edible leaves and fruits but an inedible perennial root.

I am not qualified to speak on the health of the Bushmen, but it is apparent even to the layman that they are very unlikely to suffer from any deficiency disease while on their natural diet. When they are recruited for labour and fed on an unbalanced diet their health will be undermined and they will be less able to resist the rigours of their normal life when their contracts expire.

Their study by serious workers is to be encouraged for it should lead to their stability as a race and the enrichment of our knowledge, but contacts with irresponsible strangers is unfortunate and observations like the following by Brown (1954: 130) are valueless and regrettable:—

> "They are wonderful runners. When I chased one with the clanging of a bell he set off at a good bat into the distance, and kept it up until out of sight."

During the three months in which the field work was done, the expenses of my transport and keep were met from the funds of the expedition, and this I gratefully acknowledge. Dr. R. A. Dyer, Chief of the Division of Botany, gave me the opportunity of joining the expedition, and all facilities for working up the results of the field work. Most of the determinations were done by my colleagues in the Division of Botany, and of them Miss I. C. Verdoorn, author of *Edible Wild Fruits of the Transvaal,* read through the typescript and gave me valuable advice. Dr. L. E. Codd deserves special thanks for the way he saw to the growing of the considerable quantities of roots, bulbs and seeds sent from the Kalahari. I thank Mr. L. K. Marshall, who led the expedition, and the members of it, for their interest and kindness, also Kernel Ledimo, a fluent speaker of the Eastern !khũ language, who was always ready to translate or to pilot me through its little-known and fascinating grammar and phonetics. My notes on the Bushman languages were kindly checked by Prof. L. F. Maingard, and the ethnological literature was supplied mainly by Dr. N. J. van Warmelo of the Department of Native Affairs. I am indebted to Messrs. Midgeley, Martin and Scholtz of the Bechuanaland Administration for hospitality and for enabling me to see parts of the territory that I should not otherwise have seen. My thanks would not be complete without mention of the Bushmen whose knowledge is the foundation of this paper. The information was seldom reluctantly given—usually cheerfully and with humour, and always with intelligence.

ORTHOGRAPHY.

The following are the approximate values of the letters and symbols used in the spelling of the Bushman names. They have been taken from Bleek's paper of 1929, pages 12-14.

b, d, h, k, l, m, n, r, s, w, z — as in English.
k', t' — as above, but with glottal closure.
g as in *g*et.
j as in *y*et.
k″ the velar glottal affricate.
x as German *ch*.
ŋ as in si*ng*.
ʃ as in *sh*ip.
ʒ as in vi*s*ion.
ɾ the flapped retroflex consonant.
| the dental click.
! the palato-alveolar click.
‖ the lateral click.
≠ the alveolar click.
⊙ the lip click.
a: as in h*a*rd.
a the same sound shortened.
ɑ the same sound produced far back in the throat.
e as in *ai*r.
e: as in s*ay*.
ɛ as in m*e*t.
i as in h*i*t.
i: as in m*e*.
ɔ: as in h*au*l.
ɔ the same sound shortened.
o as in n*o*tice.
u as in p*u*t.
ʔ the glottal stop.
~ over a letter denotes nasal pronunciation.
ˊ over a letter denotes accentuation of the syllable.

The middle tone is not marked, the high tone is marked by a dash above the line preceding the syllable, the low tone by one below the line, as ¯ha, ˍha; rising and falling tones are marked ˊha and ˎha.

The voiced h is written ɦ.

SYNOPSIS AND DESCRIPTIONS.

The synopsis is intended as a guide only, and leads to groups of plants and usually not to species. The descriptions and photographs should make the final identification possible, but it should be remembered that there are many Bushman food plants which were not seen on the expedition and which are therefore not described in this paper.

I have taken for granted that the reader will realise that the measurements of plants and their organs vary, and for this reason I have usually given what I consider to be the average and have omitted most words like "approximately" and "about".

Technical terms have been avoided except for the following:—

Axil of leaf—the angle between the leaf and the stem;
glabrous—without hairs;
glaucous—bluish-green, or covered with a bloom;
pappus—a tuft of hairs on a seed;
perianth—petals and sepals;
rhizome—an underground stem;
tomentum—dense short hairs;
tuber—a roundish succulent underground stem.

UNDERGROUND PARTS EDIBLE.

Trees or shrubs	*Bauhinia macrantha.* *Boscia albitrunca.* *Commiphora* spp.
Prostrate runners	*Bauhinia esculenta.* *Cucumis* sp.
Climbers or scramblers:—	
Scramblers	*Ipomoea verbascoidea.*
Twiners	*Ceropegia* spp.
With tendrils	*Coccinia* spp. *Corallocarpus welwitschii.*
Fleshy finger-like angled erect stems	*Caralluma knobelii.* *Duvalia polita.* *Stapelia kwebevris*
Without chlorophyll	*Hydnora* sp. *Terfezia* sp
Wiry 12″ stems	*Ipomoea* sp. *Raphionacme burkei.*
Monocotyledons (strap-shaped or grass-like leaves):—	
Bulb with papery coverings	*Dipcadi* sp. *Mariscus congestus.* *Scilla* sp.
Rounded storage organ without papery coverings	*Eulophia* spp. *Walleria* sp.
Horizontal rhizome	*Sansevieria scabrifolia.* *Typha capensis.*

ABOVE-GROUND PARTS EDIBLE.

Trees shrubs or palms:—	
Thorny or spiny—	
Large fruits more than 1½″ in diameter	*Hyphaene ventricosa.*
	Strychnos spp.
Small fruits less than 1½″ in diameter	*Commiphora pyracanthoides.*
	Ximenia spp.
	Ziziphus mucronata.
Pods	*Acacia* spp.
Not thorny or spiny—	
Leaves compound—	
Stems more than 2′ thick	*Adansonia digitata.*
	Ricinodendron rautanenii.
Stems less than 2′ thick	*Burkea africana.*
	Lannea edulis.
	Rhus commiphoroides.
	Sclerocarya caffra.
Leaves simple—	
Fruits winged	*Combretum* spp.
	Terminalia sericea.
Fruits not winged—	
Leaves bilobed	*Baulinia macrantha.*
Leaves not bilobed—	
Leaves hairy	*Dichapetalum cymosum.*
	Ehretia rigida.
	Grewia spp.
	Royena sericea.
	Strychnos cocculoides.
Leaves glabrous	*Boscia albitrunca.*
	Ochna pulchra.
Prostrate runners—	
Stems and leaves fleshy	*Talinum arnotii.*
Leaves bilobed	*Baulinia esculenta.*
Fruits spiky	*Citrullus naudinianus.*
	Cucumis hookeri.
	Momordica balsamina.
Fruits smooth	*Citrullus vulgaris.*
Climbers or scramblers—	
No tendrils	*Pentarrhinum insipidum.*
	Pollichia campestris.
	Sarcostemma viminale.
Tendrils—	
Fruits spiky	*Cucumis metuliferus.*
	Momordica balsamina.
Fruits smooth	*Coccinia* spp.
	Corallocarpus spp.
Fleshy finger-like angled erect stems	*Caralluma knobelii.*
	Duvalia polita.
	Stapelia kwebensis.
Fleshy slender round erect stems	*Sarcostemma viminale.*
	Talinum arnotii.
Slender lax stems about 1′ high	*Pollichia campestris.*
Stemless, with one soft leaf	*Ophioglossum sarcophyllum.*
Monocotyledons (strap-shaped leaves or fleshy leaves with spiny margin)	*Dipcadi* sp.
	Aloe spp.
	Typha capensis.

Terfezia spp. (5031, 5616) Photograph 1.

Naron Bushman..... ˌku-ts'ɪ
Eastern !khũ Bushman ˌtsu-ts'ɔ

In size, shape and colour these truffles resemble potatoes, but the skin is rough and they are not as heavy.

The genus Terfezia, which is allied to the European truffles, has been recorded from dry and sandy localities between the northern Cape Province and the Mediterranean region. There are 36 species, of which three are believed to occur in South West Africa and the Union. Some records are vague and incomplete, and cannot be checked. These southern species, all of which are edible, are not distinguishable except by microscopical examination. They may be found from April onwards to about July, when the season ends presumably through their disintergrating in the soil. Their presence depends upon the rainfall, as is shown by the following extract from a letter from Mr. G. Scholtz, of Ghanzi, whom I had asked to collect some for me. "Nature appears to be against you this year. I even offered five shillings per truffle, but according to the Bushmen (my offer was just laughed at) no rain, no truffles. And we certainly have had no rain, in fact the worst drought in Ghanzi's history."

It is uncertain whether they are root parasites or mycorrhizal fungi, and nothing definite is known as to the host plant favoured by any particular species. In the south-western Kalahari, near the Kalahari Gemsbok National Park, they are found in the dips between the sand dunes where *Aristida ciliata* is the dominant grass, but it has not yet been established whether they are connected with it or with some associated plant. Towards the Ghanzi area they were collected in a mixed grassveld of Aristida and Eragrostis species with scattered trees of *Acacia uncinata* and no *Aristida ciliata;* but here another species may have been involved.

The European truffles are usually collected with the aid of dogs or pigs, which can trace them by their scent, and rarely by two other methods. One of these is by observing where certain insects collect to lay their eggs, for their larvae feed on truffles and the eggs are laid near them. The other is to watch for cracks in the ground which the truffle sometimes causes as it grows. This is the method used in southern Africa. A good deal of practice is needed before it can be applied, for the cracks are slight, and are specially difficult to find where the surface has been disturbed by game or stock, or where they have been partly filled in by windblown sand, but matters are eased somewhat by the fact that there is seldom more than about three inches of sand covering the truffles and that they grow in patches.

They may be eaten boiled or roasted. The texture is like soft cheese. They are not aromatic and the flavour is far inferior to that of the best European truffles.

Ophioglossum sarcophyllum Desv. (5142) Photograph 2.

This unusual looking plant is one of the ferns. It is five inches high on the average, and somewhat fleshy, and consists of an erect stalk with a leaf-like undivided frond at the top. A thinner stalk which bears the spores rises from the mid-rib near the base of this frond.

A few specimens were collected at Gam, on damp sand which was moist from the run-off from adjacent rock outcrops. It is usually found in places like this, where the dampness is conserved, but after good rains its distribution is not restricted, except that it occurs more in the open and does not grow under dense bush. In favourable localities it is sometimes massed, and may be collected in quantity. It occurs throughout southern Africa.

It is used by various Native tribes as a spinach, and may also be eaten raw. It tastes like lettuce but is slightly sweeter and lacks the crisp texture of lettuce.

Typha capensis Rohr. (5302) Photograph 3.

Eastern !khũ Bushman dza-dza

A cosmopolitan and well-known plant, known in South Africa as the bull-rush, and easily recognisable from its inflorescence which forms a compact brown spike two feet or more in length at the tops of the five-foot flowering culms. This is in two parts, variously divided so that the lower may be equal to the upper, or shorter, or longer. The lower part consists of the female flowers and is sausage-shaped and brown, with the flowering culm running through its centre. Immediately above this is a spike of male flowers, similar except that it is more open and often yellowish from the masses of pollen it contains. The leaves are strap-shaped, usually an inch wide and six feet long, erect and fairly rigid and very slightly twisted along their length. It is a gregarious plant and always grows near water.

A little was growing round a permanent spring at the edge of Gautscha Pan, and was the only patch seen during the trip.

The top (male) part of the inflorescence is eaten raw by the Bushmen. It has the rich and familiar flavour of bee-bread. Dinter (1912:17) states that the rhizome of this plant is the thickness of one's finger and about two feet long, and may after drying and husking be beaten to a reddish meal which is rich in starch and may be used in the same way as meal from cereals. I have tried the rhizome myself. It is heavy and succulent when fresh, and loses water slowly. When dry it has a puffy outer zone of tissue which may be stripped off to expose a hard central cylinder containing the reddish starch to which Dinter refers. As the starch does not crumble readily it is difficult to beat out, and it is full of fibres which may however easily be removed by sifting. It may be boiled to make a brown porridge of good quality except that it is more glutinous than any porridge normally used by us.

Mariscus congestus C. B. Cl. (5166) Photograph 4.

Naron Bushman..... n!ani
Eastern !khũ Bushman !gewu

This plant is one of the sedges, a group closely related and similar to the grasses but distinguishable by certain rather subtle differences which most laymen as well as botanists are familiar with. One of the main ones is that their flowering stalks are usually three-angled and solid while those of the grasses are usually round and hollow. The species in question could not, in its withered winter condition, be named in the field, but bulbs which were collected grew well in cultivation and flowered in Pretoria that same

year. They produce an erect and robust plant with bright green leaves and numerous spreading underground rhizomes on which more bulbs are borne a few inches below the surface. Some stolons are produced above ground as well, from among the leaves. They afterwards turn downwards, entering the soil close to the parent plant and thereafter behaving in all respects like the rhizomes. The flowering stalk is three-angled and unjointed, with a cluster of compact, spiky inflorescences at the top, some on slender secondary stalks and some almost sessile. The parent plant is in a sense annual, for both it and the bulb producing it wither at the onset of winter, but the fresh bulbs which have been produced form new plants, and the species is capable of spreading very rapidly by this means. The bulbs are rounded, half an inch in diameter with a sharp point at the top, and covered with several papery brown layers which may be removed to expose a pale nut-like body.

Sedges usually favour damp places, but this species seemed equally at home in seepy areas and well-drained ones, and in the sandy country near Nama Pan it was common nearly everywhere, sometimes scattered among the grasses but more often in patches. Its range is from Cape Town to the Mediterranean, and it occurs in Australia also.

The bulbs are edible, and seemed to be a fairly important food of the northern Bushmen. The taste is sweetish and they have a crisp texture and a cloudy, very slightly astringent juice. Light roasting improves the flavour. They are easily gathered by scratching away the top layer of soil, and their presence is often shown by the disturbed soil where they grow, for they are a favourite food with many birds and small animals, which scratch and burrow to find them. According to the *Flora Capensis* the plant " has been for nearly a century cultivated in Europe ".

Hyphaene ventricosa Kirk (5301).

Eastern !khũ Bushman !hani and !hɛni

This palm is bushy when young, but loses its bushy habit as it matures, forming a long clean stem 40 feet in height with a crown of leaves at the top and often with a slight swelling near the middle. The leaf has a strong woody rhachis up to six feet long, slightly hollowed above and rounded below, with a row of sharp hooked spines at intervals of an inch or so along each margin. At its tip it bears the leafy part which is two feet across and folded like a fan. The fruits, a little smaller than a tennis-ball, are covered with a glossy brown papery skin, and are borne in clusters.

Old an half-decayed fruits were found in the neighbourhood of Nama Pan, presumably where they had been discarded by Bushmen, but the palm trees themselves were not seen in this area. Only one specimen was found, 20 miles to the north-east. It was immature and had neither flowers nor fruits. According to available records, it was growing near the southern limit of its range, which extends to northern Rhodesia and the Belgian Congo.

There is a quarter-inch edible mealy layer immediately underlying the skin of the fruit. It is fibrous and dry but sweetish, with a pleasant flavour, and may be gnawed off the hard inner shell into which it merges. The kernel in the centre of the mature fruit is hard and bony and inedible, but Chapman (1868 : II : 73) states that the milk of the young fruit may be used like that of the coconut, and that the whole of the young fruit may

be eaten after boiling, " pulp, rind and all ". Dinter (1912:21-22) says also that the Bushmen use the heart of the palm as a green vegetable, and that a sweet sap may be tapped from the upper part of the stem and fermented to make an alcoholic drink. He gives the yield of fruits from one palm as between 20 and 50 kilograms (48 to 120 lb.). His reference to the heart of the palm is obscure, but Chapman (1868:I:55-56), who is more explicit, says that this is the core of the young trunk.

Aloe rubrolutea Schinz (5135).

Eastern !khũ Bushman n‖ɔru

This species was in full bloom in early August, and made a striking show with its spikes of brick-red flowers. The plants formed rosettes of leaves 12 inches across, producing a slender erect five-foot flowering stalk. Among the hundreds of speciments seen there were none arborescent, although elsewhere arborescent forms are common (Reynolds 1950: 328). Those seen at Nama Pan were similar in habit to *Aloe zebrina.*

Aloe rubrolutea was seen only on the rocky outcrops near Nama Pan and Gam, growing in patches of an acre or so, but it has a wide distribution extending from South West Africa through the Bechuanaland Protectorate to the northern Transvaal and Portuguese East Africa.

The flowers are stripped off the flowering stalk and pounded to make a spinach-like vegetable. Although the Bushmen said that they did not eat the leaves, they were tasted raw and boiled and were found to be juicy and not unpleasant, and to have no harmful effects. They would be a good source of water in an emergency.

Aloe zebrina Bak. (4995).

!hɔ̃: Bushman..... ǁganja
ǁganakwe Bushman n‖ɔru
ǁgikwe Bushman... n‖uru
Naron Bushman... n‖ɔru

The plant forms a rosette of rigid dark green leaves which have pale transverse bands and numerous sharp teeth along the margins. It may have a stem 30 centimetres long (Reynolds, 1950: 282), but those seen on the expedition were stemless. The flowering stalks were three or four feet high. The sap in the epidermis of the leaves is greenish-yellow. It oozes out of the vessels fairly quickly if a leaf is cut across, and hardens and changes colour on exposure to the air, becoming brown and glassy. The bulk of the sap, which is in the inner part of the leaf, is colourless and translucent, and does not ooze out if the leaf is cut.

Only one small clump of this Aloe was seen, on deep sand about 80 miles directly south-east of Ghanzi. It is, however, recorded from Angola and South West Africa and across the continent to the east.

The Bushmen stated that the leaves were a good source of water. One of these plants was sent to Pretoria and grew well in cultivation. On being tested, the leaves proved extremely unpleasant, not because of any bad taste but because their sap is in the form of a thick, revolting slime. Boiling or roasting did nothing towards making them more palatable. Either the Bushmen were confusing this Aloe with another species, or it

is eaten only when they are in the greatest need. Reynolds (1950: 285), quoting W. B. Hooker, states that its flowers may be eaten after boiling, but I did not think of asking the Bushmen about this, and they did not volunteer any information.

Dipcadi sp. (5163, 5307).

!hɔ̃: Bushman..... n!ɓɔm
Naron Bushman..... n!ɔm
Eastern !khũ Bushman n!umʃé:

Although the above-ground parts had been killed by frost, enough remained for the plant to be identified as a species of Dipcadi. The bulbs were two inches below the surface of the soil, in appearance like a small onion. They were planted in Pretoria, but although they were still alive two years after being collected, they had failed to produce leaves or flowers up to the time this report was written.

Specimens were collected at Nama Pan, in parkland on sandy soil. As the plant was recognised and named by one of the southern !hɔ̃: Bushmen who was with us, it probably extends into the Kalahari well south of Ghanzi.

The bulbs are edible after cooking.

Scilla sp. near *Scilla lancifolia* Bak. (5190) Photograph 5.

Eastern !khũ Bushman tũ

This plant has a rounded two-inch bulb covered with a thick layer of dark brown papery scales. In the summer it produces three or four spreading leaves, usually six inches long but up to 10, and one and a half inches wide at the widest part. They are thin but fleshy, strap-shaped (but in section widely V-shaped near the base), and light green, sometimes faintly mottled with darker green. The inflorescence is four inches long and the flowers small and not conspicuous, with purple stamens and a recurved perianth.

It was common in shallow sand overlying rock near Gautscha Pan and Nama Pan but was not easy to find because the leaves and inflorescences had been frosted, and blown away by the wind by the time the expedition had reached those parts. A number of bulbs collected there produced leaves and flowers in Pretoria the following summer, and it was from these plants that the notes were made.

The bulb is edible after roasting but I have not tried it personally.

It would be dangerous to experiment with plants like this if what the Bushmen say is true, for it could be easily confused with another species which has an inedible bulb. The inedible species (No. 5181) is shown in photograph 6 and may be distinguished by its longer bulb and longer leaves (10 inches long and over, and two inches wide at the widest part). They have a translucent fringed margin, are pointed, narrowly V-shaped in section and more numerous, about 12 to a plant. In addition, the

older leaves are marked at the base on the lower surface with narrow wavy black bands. Specimens were collected in sandy soil in open parkland near Nama Pan and flowered in Pretoria the following summer. The leaves and inflorescences, like those of the edible species, die back during the winter.

Neither of the two species could be named in the National Herbarium, for the genus is not well documented and badly in need of revision.

Sansevieria scabrifolia Dinter (4951) Photograph 7.

!hɔ̃: Bushman.....	|xa-ji
||ganakwe Bushman...	!gwi:
|gikwe Bushman.....	!gwi:
Naron Bushman.....	!gwi:
Eastern !khũ Bushman	!hwi:

A stemless plant with bunches of stiff, erect, strap-like leaves 10 inches long and a little less than an inch wide, concave on the front or upper surface and rounded on the back, and without a midrib. They rise at intervals of a foot or so, and in tufts of up to a dozen, from a brown-skinned horizontal rhizome three inches below the ground, and are light green mottled with dark green. They are tough and fibrous rather than succulent, which is the term that has been used to describe the leaves of closely allied species. The plants may occur singly but are more often massed in communities 20 to 50 yards across. Those sent to Pretoria for growing have never thrived and never flowered, nor were they seen flowering in the field, but it is known that the inflorescence is spike-like along a 12-inch flowering stalk, and that it consists of crowded usually off-white flowers half an inch across. Flowering seems to occur rather rarely and sporadically in the genus as a whole.

This species was widespread and fairly frequent north and south of Ghanzi. It was not found in the open grassland but always among trees and scrub, though not necessarily shaded by them.

The rhizome is a useful source of water. It has a crisp, white fibrous flesh which is juicy and, although slightly bitter, not unpleasant. There are several species of Sansevieria growing in cultivation in Pretoria all alike in habit, and all have been tested. There is no perceptible difference in the taste or juiciness of any of them.

The leaf fibres of the plant described are used by the Bushmen in making a string of surprisingly good quality.

Wallera nutans Kirk (5311) Photograph 8.

Eastern !khũ Bushman	tʃũ

The plants are about six inches high, with a slender erect central stem bearing paired light green grass-like leaves, strongly keeled and somewhat fleshy and faintly crystalline on the surface. Both the stem and the keel of the leaves are sparsely covered with short soft spines. Three or four strongly scented nodding flowers are borne, superficially very like potato flowers. There is a firm round storage organ a few inches below the surface of the ground, slightly larger than a golf ball and the colour of a new potato.

Two storage organs of this plant were found by the Bushmen near Nama Pan in August 1955. They lay dormant for a further 16 months after being planted in Pretoria, then both plants grew out and flowered within a few weeks of each other. The parts above ground disappear during the winter for they are very susceptible to frost.

The storage organ is edible. It has a pasty texture and little taste if eaten raw, but is improved by baking.

Eulophia sp. nearest *E. pillansii* Bol. (5279, 5304) Photograph 9.

Eastern !khũ Bushman ≠gɔ?ɔ

An erect stemless plant with four or five spreading glabrous grass-like leaves half an inch wide and 11 inches long, prominently three-keeled on the back and grooved above, and fairly soft and lax. They rise in tufts, each one from a corm the size and shape of a slightly flattened golf ball with "eyes" on the upper surface and short stout roots below. The corms have a brown skin covering a white fairly firm flesh. They are often linked together five or six at a time, and are to be found an inch or two below the sand. The above-ground parts die back during the winter and usually disappear without trace before the next season's growth begins. The plant flowers after the new leaves appear and has the flowers arranged alternately in an open inflorescence at the end of a 12-inch flowering stalk. They are yellow and green, and about half an inch long.

A few corms were found by chance in two places near Nama Pan, in the shelter of small thickets. They flowered in Pretoria but could not be matched with any of the named specimens in the National Herbarium and the species may be undescribed.

The corms are edible raw or roasted. They were peppery when tasted in Pretoria, probably because they had been planted too near the surface and had become green through the action of the light. At Nama Pan they were mild and tasteless with a pasty texture.

Eulophia sp. (5213, 5306) Photograph 10.

Eastern !khũ Bushman ≠gawu

The corms of this orchid are a little bigger and coarser than those of the other species of Eulophia (numbers 5279 and 5304) but are otherwise similar. The leaves are erect, somewhat curved, eight inches long and slightly more than half an inch wide, pale yellowish-green, rigid and firmly fleshy, with a channel running down the upper surface and a corresponding keel on the lower surface. This plant grew well but did not flower in cultivation in Pretoria and the species has not been determined.

It was found in the same locality as the other Eulophia and under similar conditions.

The corms of the two species are used in the same way by the Bushmen, and cannot be distinguished by taste or texture.

Ximenia americana L. var. *microphylla* Welw. ex Oliv. (5061) Photograph 11.

!hɔ̃: Bushman..... n≠ ?uri
ǁganakwe Bushman... n≠ ?uri
ǀgikwe Bushman..... ≠ɔǂi
Naron Bushman..... n≠ ?uri

Very like the following species (*Ximenia caffra*), but except for the flowers glabrous throughout and with smaller glaucous leaves which tend to fold along the midrib and droop, giving it a rather unattractive look. Its fruits are lighter in colour, and smaller. The two species were often found growing together, but no evidence of hybridisation was seen.

It is recorded from South West Africa, the Bechuanaland Protectorate, the Transvaal, Portuguese East Africa and Natal. On the expedition it was not seen north of the Ghanzi area but near Ghanzi and to the south it was widely scattered, and sometimes fairly common in small patches.

The fruits are edible, and the remarks on the fruits of *Ximenia caffra* apply to the fruits of this species also. Ripe fruits were found at Ghanzi in July, although fruiting is usually over by then.

Ximenia caffra Sond. (4949) Photograph 12.

!hɔ̃: Bushman..... n≠ ?uri
‖ganakwe Bushman... n≠ ?uri
ǂgikwe Bushman..... ≠ɔɨi
Naron Bushman..... n≠ ?uri

A stout or straggly evergreen bush or small tree, usually about six feet high, with soft brittle branches and knobby rough twigs which are densely leafy and sometimes end in a sharp spine. There are often spines in the axils of the leaves as well. The leaves are dark green and tend to curve backwards slightly, and they and the young twigs are softly hairy. The flowers appear in early summer. They are massed along the twigs and have four recurved green petals with conspicuous white hairs on the inside. The fruit is the size of a plum, and an attractive light red.

It probably occurs in Angola, for it has been recorded from northern South West Africa near the Angola border. It is also known from Northern and Southern Rhodesia, the Bechuanaland Protectorate, the Transvaal, Portuguese East Africa and Natal. Like the other species of *Ximenia,* it was not seen along the route of the expedition north of the Ghanzi area.

The fruit is edible. It has a bitter skin and a large stone, and a reddish pulp between them, pleasantly flavoured but astringent and sour, and particularly sour next to the stone. It is at its best when over-ripe, for it does not become soft and unpleasant as many fruits do, but dries out slightly, becoming wrinkled in the process and more mellow, with the flavour of a prune. The stone is rich in oil, but this is said to be very pungent (Marloth, 1913-1932: I: 165) and to contain a rubbery substance (Schweikerdt, 1937: 179-182). The Bushmen use it to anoint themselves but do not consider it edible. It has been tested in England for possible commercial uses, but it was decided that the oil was not worth extracting.

Hydnora sp. (5162) Photograph 13.

Eastern !khũ Bushman ‖hɔk?am

This curious plant is parasitic on the roots of *Combretum hereroense.* It is almost completely subterranean and is without chlorophyll. There is very little of the plant until it produces its flowers and fruits, which are much larger than the vegetative parts. The fruits are buried a few inches deep and are the size and shape of a pomegranate, but have a dark roughened woody shell split by many fine irregular cracks. The inner skin which shows through is red until the fruit ripens, when it becomes white. If the fruit is cut open a large, slightly sticky mass of pin-head brownish seeds is exposed, embedded in a pasty matrix which fills the inside of the fruit but is separate from the shell. Flowering was over by the time the first specimens were seen, but it is known that the flowers of this genus have a smell of carrion and that they protrude above the ground, where they can be reached by the insects necessary to bring about their fertilisation. They have no petals or sepals in the usual sense, their

place being taken by a few thick fleshy erect lobes, and from the woody remnants of old flowers in this particular species it could be seen that they had four lobes. The two species recorded from South West Africa are *Hydnora africana* and *Hydnora solmsiana,* parasitic respectively on species of Euphorbia and species of Acacia. Number 5162 is either a new species, or one of the known ones parasitic on a hitherto unrecorded host. The material collected was inadequate for specific determination, and the seeds which were planted did not germinate.

This Hydnora was seen only in the immediate neighbourhood of Nama Pan, where it appeared to be fairly frequent.

The host plant is a straggly shrub up to six feet high, with grayish woolly leaves an inch long. It has the characteristic four-winged fruits of the genus, and many remain on the twigs through the winter. It was not seen in the country to the south of Ghanzi, but was common from Ghanzi northwards, and is widely distributed in Portuguese East Africa, the Transvaal and Rhodesia. A glossy-leafed form of it is also known, but was not seen along the route of the expedition.

The whole mass inside the Hydnora fruit is edible. It is astringent and slightly sweet, and is eaten raw. The fruits would be difficult to find if it were not that they are eaten by various animals. A litter of half-eaten fruits and fragments of rind and shallow burrowings often show where the fruits have been excavated, and where more may be expected. They ripen about the end of August.

Talinum arnotii Hook. f. (5256) Photograph 14.

Eastern !khũ Bushman ǁgwi-ja (stems and leaves)
≠k″arɔ (tuber)

During the winter there is seldom any sign of this plant above ground for the branches wither and die back with the first frosts. There is a perennial tuber a few inches underground, irregularly shaped and up to a pound in weight, crisp in texture and exuding a little cloudy astringent juice when injured. It has a brown skin and a reddish-brown zoned flesh. Although it is often eaten into hollows, presumably by rodents and insects, it is not eaten by the Bushmen. The stems appear in September and form a loose mat three feet in diameter on the surface of the ground. They are reddish-brown, prostrate and sappy, and the leaves are dull green and fleshy, channelled down the centre on the upper surface and with slightly crystalline appearance. The bright yellow flowers, which are produced in midsummer, are an inch across and quite showy, but open only in the heat of the day. They have two sepals and five petals. The flower-stalk starts bending when the flowers are mature, and by the time the fruits are fully formed it is curved sharply back. The fruits are the size of a small pea, shiny green and pointed at the tip, and covered by the withered remains of the perianth. They become yellow when ripe, with a papery shell and seeds the size of a pinhead.

The tubers of this plant were often unearthed in the more open parts round Nama Pan. I am doubtful whether it should be kept separate from *Talinum caffrum,* which is distributed from the Cape Province northwards to the Sudan and is very variable in its leaves and habit.

The leaves and smaller branches of this species are used by the Bushmen as a green vegetable. They are usually prepared by being pounded in a mortar to a paste which is dark green and slightly slimy and has a faintly acid taste with a flavour of lettuce.

Pollichia campestris Ait. (4963, 5040) Photograph 15.

A small grey-green bush with much-branched slender soft stems, fairly compact when growing in the open but usually found as a semi-scrambler up to four feet high. The leaves arise in tufts of about three, the tufts being opposite each other and at intervals of anything up to an inch along the stem. They are lanceolate and usually under half an inch long. The plant bears what at first sight appear to be fleshy translucent fruits like small white or yellowish mulberries, but which are actually parts of the flowers.

This is a widespread plant throughout Africa, and was seen at intervals all along the route taken by the expedition.

The fleshy parts of the flowers are edible and sweet, with a queer earthy flavour, and are loosely attached so that they may be easily collected by pulling the stems through the hands. The plant, however, did not appear common enough to be of importance as a food.

Boscia albitrunca (Burch.) Gilg and Benedict (4998, 5208) Photograph 16.

!hõ: Bushman.....	≠hun
ǂganakwe Bushman...	n|ʃu-ni
ǂgikwe Bushman.....	n|ʃu-ni
Naron Bushman.....	n|ʃu-ni
Eastern !khũ Bushman	zã

This is a rather variable tree, sometimes with erect branches and sometimes with a spreading crown, usually bearing many thin twigs with much dead wood among them. The bark is sometimes loose, dark and coarsely fissured and sometimes white and flaky. The species was also often seen in the form of a many-stemmed shrub about four feet high. It is evergreen, and did not seem to be at all affected by the heavy frosts that were experienced in the central Kalahari. The leaves arise singly or in bunches of four or five from small knobs on the twigs, and are leathery and about one inch long and a third as wide. Although the flowers are small and inconspicuous as individuals, they are borne in masses towards the tips of the twigs and make quite a show. In the Cape and the Transvaal at least the tree appears to be sporadic in its flowering. The fruits are borne on half-inch jointed stalks, and are half an inch in diameter, pale-skinned and translucent, with several large stones surrounded by a thin, watery pulp.

The tree was scattered evenly throughout the country from Molepolole to Ghanzi and Gautscha Pan, and has been recorded from the Cape Province northwards to the tropics. It occurred singly, occasionally in open communities, but it was never seen to form thickets.

The fruits are eaten by the Bushmen, but they do not make pleasant eating, for the pulp has a rather slimy texture and a sickly-sweet taste.

Sim (1907:123) refers to a meal which is prepared from the roots by drying and beating them. The resulting meal is then sifted to remove the fibres and may be made into a porridge. There are reports of gastro-intestinal disturbances after the eating of Boscia roots, but the reports have not been confirmed, and Steyn (1934: 561) fed large quantities to a rabbit without ill effects. It is suspected that people are susceptible only when they are not accustomed to this food. The Bushmen were not asked about their use of the roots, and did not volunteer any information.

The older trees are often hollow, and form natural reservoirs for rain water which is tapped by the Bushmen. (See Adansonia.)

Acacia species.

The species of Acacia mentioned in this paper often exude edible gum from injuries on the stem. It is a safe assumption that the gum from species that are not mentioned would also be edible, for none are known to be poisonous. All African species have alternate bipinnate leaves of the pattern shown in the photograph of *Acacia heteracantha,* and all are thorny.

Acacia detinens Burch. (4947, 5070, 5206).

!hɔ̄: Bushman.....	ǁwa
ǃganakwe Bushman...	ǁwa
ǃgikwe Bushman.....	ǁk″uwa
Naron Bushman.....	ǁwa
Eastern !khũ Bushman	!gõũ

A rigid shrub usually seven or eight feet high, with a smooth dark bark and paired hooked thorns a quarter of an inch long. It makes a bright show towards the end of August, for it is deciduous and the flowers appear in profusion before the new spring leaves. The flowers are scented and creamy, and massed in round heads up to half an inch across. The pods are flat and papery, two inches long and half an inch wide.

This was the most widespread of all the Acacias seen on the expedition, and was scattered all along the route. It is found in the northern Cape Province, the northern Transvaal, the Bechuanaland Protectorate, South West Africa, Angola, and Northern and Southern Rhodesia.

It produces an edible gum.

Acacia dulcis Marl. and Engl. (5042).

A semi-deciduous tree usually about 25 feet high, with a number of erect three-inch stems arising from a common rootstock, and with a pale papery bark which has a tendency to peal. The thorns are paired and strongly hooked, a quarter of an inch long, stout, sharp and numerous. The flowers are borne in pale yellow spikes, and the pods which follow are flat and papery.

Only a few specimens were seen along the route of the expedition, all of them within a radius of 40 miles or so of Ghanzi. The tree occurs in the north-eastern Transvaal, the northern Cape Province, the Bechuanaland Protectorate, South West Africa, Angola and Nyasaland.

Its gum is said to be of a particularly good quality.

Acacia fleckii Schinz (4943, 5067, 5205).

Eastern !khũ Bushman n≠ŋ

A semi-deciduous shrub from six to eight feet high, very similar to *Acacia dulcis,* with the same pale flaky bark and hooked thorns and the same type of flower and pod, but with a different habit and usually finer leaflets.

Except between the Mabeleapudi hills and Tsau, where it was not noted, it was plentiful all along the route of the expedition. Its range is from the northern Transvaal through the Bechuanaland Protectorate and South West Africa to Angola.

It produces an edible gum.

Acacia giraffae Burch. (4945, 5069).

Eastern !khũ Bushman |ana

A tree, usually erect, with an umbrella-shaped crown and grayish foliage, darker green in the spring. Recognition is made easy by the gray woody pods, which are velvety on the surface and the size and shape of a flattened kidney, and which are to be found on and around the tree at all seasons. The flowers, which begin to appear in September, are scented and borne in small bright yellow heads, and the thorns are in pairs and stout. The bark is gray and fissured, and the crown rather dense, with much dead twiggy wood in it.

This tree was found all along the route between Molepolole and Gautscha Pan. As a rule it was scattered, but in one area, between Lake Ngami in the south and Tsau in the north, along the border of the Okavango swamps, it was the dominant tree. Some magnificent old specimens up to 30 feet in height were seen here. On the heavy sand between Molepolole and Ghanzi, however, it often occurred in the form of a shrub about six feet high. It is known from the northern Cape Province, the Orange Free State, the Transvaal, the Bechuanaland Protectorate, South West Africa and Angola.

Its gum is edible, slightly astringent but quite good to eat when fresh and clear. It becomes discoloured at times and is then less palatable.

Acacia heteracantha Burch. (5341) Photograph 17.

Eastern !khũ Bushman |gali

This tree usually has an umbrella-shaped or flat crown and a delicate lacy appearance because of its slender twigs and fine leaflets. The flowers are borne in round white heads and produce small clusters of tightly curled pods. Like *Acacia uncinata* if has straight as well as hooked thorns.

It has been recorded from South West Africa, the Bechuanaland Protectorate and the northern parts of all four provinces of the Union, and extends as far north as Tanganyika, yet in spite of this wide distribution it was not seen between Molepolole and the Ghanzi area. There is at present no explanation for this strange gap in the centre of its distribution.

It produces an edible gum.

Acacia uncinata Engl. (4950).

!hɔ̃: Bushman.....	!ɔla
ǁganakwe Bushman...	′!ũ
|gikwe Bushman.....	′!ũ
Naron Bushman.....	′ǁgũ
Eastern !khũ Bushman	′!gũ

A spreading 20 foot high tree, with a fissured bark and paired thorns, some of them straight and slender but most short and hooked. In this it resembles *Acacia heteracantha,* but its pods are straight and not curly as those of *Acacia heteracantha* are, and it is a stouter tree. The flowers are borne in round yellow heads half an inch in diameter.

There was no commoner Acacia than this from Molepolole to the Ghanzi area, but north of Ghanzi it became scarcer, and patchy in its distribution. It extends from the northern Cape Province through South West Africa and the Bechuanaland Protcetorate to Angola.

It furnishes the Bushmen not only with an edible gum, but also with the material for making quivers. These are made from the lateral roots, which are a foot or so below the surface. A suitably straight length is exposed and cut through, and after the cortex has been loosened by gently pounding it, it may be slipped off the woody central portion. The tube so obtained is then covered at one end with skin. The roots of this tree, like those of *Acacia giraffae,* have a most unpleasant smell when cut, something which is not apparent in the above-ground parts.

Burkea africana Hook. (5332) Photograph 18.

Eastern !khũ Bushman -!k″u

An evergreen tree, with attractive drooping grayish compound leaves which are silvery when young. The tips of the youngest twigs are covered with a dense reddish pubescence, but this soon wears off and the older branches and the stem have a dark brown rough bark. The flowers are small but massed in showy hanging spikes six inches long and as thick as a pencil. They are cream-coloured and scented, and produce flat one-seeded or two-seeded pods two inches long. In the Transvaal the tree has a spreading crown. Beyond Tsau the habit was very different—the branches were ascending and shorter and gave the tree a slender appearance almost like a Lombardy poplar.

It is a widespread species in tropical Africa. extending from the Magaliesberg northwards to Abyssinia and Nigeria (Codd, 1951:61). Along the route of the expedition it was scattered from the south up to a point 171 miles from Molepolole, after which it was not seen again until 65 miles north-west of Tsau. It was found only on heavy sand, and beyond Tsau where sand and hard soil sometimes alternated at intervals of a mile or so the corresponding zones of Burkea were sharply defined. The central gap in its distribution is probably a climatic one, for there was deep sand in this area and conditions were apparently ideal for Burkea.

Burkea occasionally produces a little edible gum from injuries, but it is more important indirectly because of being the host of at least two edible caterpillars, one being the larva of the moth *Nudaurelia bellina* Westwood. This caterpillar is in length and thickness slightly bigger than one's little finger. It is marked with black dots on a yellowish-green ground, with a black transverse band just below each segment and a row of stiff black bristles on each segment. It is recorded from South West Africa and is no doubt known to the Bushmen and eaten by them, but as the expedition passed through those parts too early in the season no specimens of the caterpillar were seen. The Bushmen did bring in the pupae of what they said was an edible caterpillar, and Mr. L. Vari of the Transvaal Museum was unable to distinguish them from the pupae of *Nudaurelia bellina.* One cannot, however, assume from this that they are in fact the same, for the pupae of different species in this group may be indistinguishable.

Another caterpillar found on Burkea and recorded also from South West Africa is the larva of the moth *Cirina forda* Westwood. It is black below and silvery or golden yellow above, with a line of black markings down the centre of the back. It is sparsely covered with long white hairs. Many other species of caterpillars have similar hairs which are extremely irritant, but these are quite harmless.

The following observations were made in the Transvaal near Pretoria, where infestation by *Cirina forda* is frequently so heavy that the affected trees may be readily recognised from a distance from the way in which the leaves are stripped. The caterpillar is prepared for food by being grasped by the head and squeezed through the thumb and forefinger of the free hand with a milking action. This clears out the bowel contents, and no further preparation is necessary before the boiling which follows. The head is rather hard and may be removed, but this is not necessary. After light boiling or roasting the caterpillars are dried in the sun and may be stored without deteriorating for several months. They are slightly oily but crisp in texture, with the smell and flavour of kippers.

Bauhinia esculenta Burch. (5160) Photographs 19 and 20.

Eastern !khũ Bushman tsi: (the seed)
n‖ŋ (the storage organ)

This plant is a runner in open grassveld, with numerous slender vines up to 18 feet long, the youngest parts of them covered with a fine brown tomentum. They bear inch-long Y-shaped tendrils, but the plant is not a climber. The vines die back during the winter but do not disintegrate as readily as those of the Cucurbitaceae, and are conspicuous until the new runners are produced from the perennial underground stem. The leaves, which are soft and reddish-brown when young but turn leathery and glaucous as they grow older, are deeply bilobed, with a small spur between the lobes. The plant bears showy yellow flowers in December, and the pods ripen from April onwards. At first they are soft and reddish brown, then light green and, when ripe, brown and woody. They contain up to six flattened seeds about the size of one's thumb nail, consisting of a hard shell and a soft nutty edible inner part. The plant is easily seen because of the craters it forms where the soil is stony—craters a yard or more across, edged with a ring of stones which appear to have been forced to the surface by the stem beneath. The details of this crater formation, however, are not known.

This Bauhinia is curiously patchy in its distribution. Although it is plentiful in some places near Vryburg, it was not seen along the route of the expedition until a point 400 miles north of Vryburg, that is, 127 miles before Ghanzi was reached, and I have no record of it after leaving the Ghanzi area until the expedition crossed the border into South West Africa near Gam, after which it was again plentiful. It occurs in communities sometimes miles across, with the plants in these communities scattered 20 to 30 yards apart. On the expedition it was seen growing only on deep sand or where there were outcrops of limestone, and near Pretoria it has so far been seen only on the dolomite, but it has been grown successfully in Pretoria on neutral shaly soils. It has been recorded from the northern Cape Province, the western Transvaal, the Bechuanaland Protectorate and South West Africa.

Although the seeds are not pleasant to eat when raw, they are excellent after roasting, and analysis figures show that they are rich in protein and oil. The roasting should be carried out slowly, otherwise they may shatter with a rather disconcerting report, and to avoid this they are often roasted in sand, which probably gives a slower and more even heat. They may also be boiled to make a porridge or a drink. They will last through the winter in the field without spoiling but become scarce towards the spring, probably through being covered with wind-blown sand and being eaten by animals.

The sappy young tuber makes a good vegetable after baking or boiling. Those dug up by the Bushmen were about two pounds in weight and would not have been more than a few seasons old, for it is known from specimens grown from seed in Pretoria that it takes about ten years for them to reach 30 pounds. Burchell (1824: 589) says that they are astringent, but on tasting the 30-pound one mentioned I did not find it so. It was, however, rather tough and leathery.

With breeding, this might become a useful plant of cultivation.

Bauhinia macrantha Oliv. (4887) Photograph 21.

!hɔ̃: Bushman.....	ǀintɛ
ǁganakwe Bushman...	nǀanǀhɛ
ǀgikwe Bushman.....	n≠an≠ɛ
Naron Bushman.....	n≠i≠ei
Eastern !khũ Bushman	≠ŋ≠wa

This species is usually a rigid three-foot shrub, but grows up to six feet where protected from fire and is sometimes found as a weak scrambler with stems up to 12 feet in length. Dinter (1912: 28) records one in the form of a tree five metres high, but this is quite exceptional. It has thin rather wiry twigs, some slightly curled at the tips, and alternate bilobed leaves which are shed during the winter. The younger parts are minutely hairy, but soon become glabrous. The flowers are borne at the tips of the twigs and are pure white and showy, with a pleasant scent and crisped petals. The pods are four inches long and one inch broad and contain five or six irregularly-shaped flattened beans.

Bauhinia macrantha has been recorded from near Molepolole, but is probably localised or uncommon there, for on the expedition it was first seen 60 miles northwest of Molepolole. From there on it was common, although there were occasional gaps in its distribution. It forms communities in open sandy grassy country, usually with the tips of the bushes just showing above the grasses, and has been recorded from the Transvaal, the Bechuanaland Protectorate, South West Africa, Rhodesia and Angola. It has grown well as a cultivated ornamental shrub as far south as Grahamstown.

The ripe beans are extracted from the pods, roasted peeled and pounded into a pleasant-tasting coarse rather gritty meal, edible without further preparation. The beans may also be used when they are green, but then it is more convenient to roast the whole pod so that it can more easily be opened. They are not eaten raw, for unless cooked they have a burning taste. The pods are easily opened when mature by bending them across the middle, when the two halves spring apart. The halves form spirals as they dry.

The importance of this species as a food plant was shown by the heaps of empty pods which were found at many Bushman shelters and Bakalahari villages. There is, however, a great deal of labour involved in preparing the meal, because although the beans have a thin shell and are thus easy to crack, it still takes about 1,500 of them to produce a pound of air-dry meal.

A note on one of Schoenfelder's specimens in the National Herbarium states that the root is also edible when roasted.

Like *Bauhinia esculenta,* this might be a useful cultivated plant if improved by breeding.

Vigna dinteri Harms (5227, 5310) Photograph 22.

!hɔ̃: Bushman..... |iɨi
Naron Bushman..... |iɨi
Eastern !khũ Bushman ʃa:

A leafy twiner which climbs through trees and shrubs to a height of six feet or so. It produces numerous slender stems like a runner bean, and the leaves too are similar, being alternate and made up of three pointed and often lobed leaflets two inches long and half as broad. The terminal leaflet has a stalk over a quarter of an inch long, but the side leaflets are very shortly stalked. There are two narrowly triangular stipules where the leaf-stalk joins the stem, an eighth of an inch long and fixed at the base. The whole plant is finely hairy, but less so on the upper surface of the leaves than on the lower. The flowers are also like those of the runner bean, creamy to brownish-yellow, and are borne several at a time on a stalk up to five inches long. The pods are three inches long, circular in section and less than a quarter of an inch in diameter, and the seeds are bean-shaped but small, the size of a match-head. On a branching system of roots nine inches below the surface of the soil are borne swellings the size of potatoes, but more regular in outline and without the lobing which is so common with potatoes. In shape they vary from spherical through ovoid to long and only slightly thickened, and arise apparently in no particular order, for very small ones and large ones may be found next to one another on the same root, the spacing between them ranging from a fraction of an inch to a foot. The axis of the root (which is usually a little less than a quarter of an inch thick) passes through the centre of the swellings. As the plants were seen during the winter, there was very little remaining of the leaves and stems, and I have no information as to their frequency. Only two specimens were found, both in the neighbourhood of Nama Pan, and both in fairly thick mixed scrub in sand. Because of their habit of growth, it is unlikely that they would be found in open grasslands. The root swellings were planted in Pretoria and produced vigorous plants which flowered and set seed normally. The swellings themselves, however, were found to have been heavily infested with eelworm in their new habitat, and when they were replanted no further plants were produced.

Vigna dinteri has seldom been collected, and, as far as I know, only in South West Africa, though it is very likely that it extends into Angola and the Bechuanaland Protectorate as well. The fact that it is known to the !hɔ̃: Bushmen indicates that it may extend into the central Kalahari.

The swellings on the roots are edible raw or cooked, and are a pleasant and satisfying food. When raw they have a flavour which has been likened to that of grean beans. This is fainter after cooking.

It would be worth while investigating this plant with a view to bringing it into cultivation.

Vigna triloba Walp. (5257).

Eastern !khũ Bushman ga-ni

Although occasionally reported as a trailer in grasslands, the more usual form of this plant is a twiner very similar in habit to *Vigna dinteri*. It has the same type of trifoliolate leaf as well, but the leaflets may vary widely in different plants, being simple or lobed, hairy or almost glabrous, sometimes long and narrow and sometimes almost as broad as they are long. Some of the forms would be indistinguishable vegetatively from *Vigna dinteri* if it were not for a difference in the stipules. In *Vigna*

triloba they are what is known as dorsifixed, that is they are fixed a little way up from the base so that the stipule is free at both ends. The flowers are the same size in the two species and have the same long stalk, but those of *Vigna triloba* are predominantly purple. They tend to open in the early morning and to close during the heat of the day.

Vigna triloba is reported from a variety of soils and is widespread through southern Africa, but it was not seen on the expedition until the Nama Pan area was reached.

It has a finger-thick tap-root which is edible after boiling or roasting, although fibrous and slightly bitter. In mature plants it may extend downwards further than can conveniently be dug, but it is easily broken off. There appear to have been no previous records of its use as a food plant.

Commiphora pyracanthoides Engl. (5137) Photograph 23.

Eastern !khũ Bushman n|ɓɔ

A deciduous, rigid, twiggy two-foot shrub with spine-tipped twigs, branches that curve downwards, and a bark that is pale green and flaky on the older parts and grayish on the young twigs. The flowers are less than a quarter of an inch long and inconspicuous, and are borne in bunches on small knobs scattered along the twigs. Male and female flowers are on separate plants. The knobs also bear the leaves, which appear after the flowers and are glaucous, simple and finely serrate, and about three quarters of an inch long and half an inch wide. The fruits are " ovoid, about the size of a green pea, though reddish brown when ripe. When the fruits are ripe, the fleshy covering may be easily split apart in two halves exposing the black seed with a red aril covering it partly at the base and extending in four slender ' fingers ', producing an intriguing pattern ". (Codd, 1951 : 87.)

The species extends from South West Africa to the northern Transvaal, but was uncommon in the area round Nama Pan. One specimen collected there was grown in Pretoria. Leaves and flowers were obtained in the summer following, and from this material the determination was made possible.

The plant exudes an edible gum from injuries and is a useful source of water in an emergency, the water being in a sappy underground organ which is like that of one of the following species of Commiphora, No. 4994. It is known as a water plant among the Bantu of the Transvaal as well.

Commiphora spp. (4994 edible, 5030 inedible).

4994		5030	
!hɔ̃: Bushman..	dʒã	ǂgikwe Bushman	!ana
ǂgikwe Bushman	dʒã		
Naron Bushman	ǀuri		

Two species of Commiphora were collected in the Kalahari south of Ghanzi. They were completely deciduous rigid two-foot shrubs with many sharply-tipped twigs and a flaky bark. At first sight they were identical, and even close examination revealed no bigger difference than that one of them was a little more of a thicket than the other and slightly grayer. The Bushmen, however, stated emphatically that the grayish one was poisonous and the other not. They said also that the grayish one

was the host of the insect which they use for making their arrow poison, and that it had harder roots than the other. The fruits, flowers and leaves might have shown the difference clearly, but no trace of them could be found, and though plants were sent to the Transvaal for growing they failed to become established.

In spite of its unpromising appearance, the non-poisonous one is a useful source of water. This is in a sappy unbranched vertical underground part about an inch and a half thick. The Bushmen excavate down its length as deeply as they can reach, then break it off and withdraw it. They remove the thin outer skin and chew the remaining part, which is crisp and has a little tasteless sap. As a source of water it does not compare with the various species of Cucurbitaceae—weight for weight it contains far less, and the labour of digging it up is considerable. However, it must be a reliable standby when the Cucurbitaceae are not in fruit, and in the central Kalahari it is plentiful. In the southern part it is apparently absent, for it was not seen until 256 miles north-west of Molepolole.

Dichapetalum cymosum (Hook.) Engl. 5109, 5266, 5338 Photograph 24.
Eastern !khũ Bushman ma-ĩ

This plant produces a number of slender erect woody stems up to 12 inches high, sparingly branched and often buried in the sand at the base. The leaves are four inches long, numerous, sessile, alternate, broader in the upper half where they are about one and a half inches across, and tapering at the base, with a stiff papery texture and with veins prominent above and below. They have a slight bloom on the upper surface and the younger leaves at least have a pair of narrow hairy stipules at the base. The younger parts of the plant are hairy, but the hairs wear off with age, and during the winter the leaves turn brown and hard and finally drop. The flowers are scented and have white petals forked at the end, but as they are small and nearly covered by the sepals, they are not conspicuous. The fruits are like a loquat, and may be brown or yellow. The have one or two big seeds covered by a little flesh.

Dichapetalum is distributed widely but patchily from the northern Transvaal through to Angola and Rhodesia. On the expedition it was seen for the first time between Tsau and Kaikai, and beyond that it was fairly frequent but scattered. It was usually in open situations, and seldom where there was dense tree growth.

Though the leaves are extremely poisonous, the flesh of the fruits is harmless and is eaten by the Bushmen. They emphasised that the flesh only could be used, and that the stone was poisonous. They did not mention the skin, but the following note on Schoenfelder's specimen 31, in the National Herbarium, indicates that it, too, is poisonous:—

> "Fruits like small yellow oranges are eaten peeled in great quantities by the Kung Bushmen. When still green can be eaten after baking in hot ash. Used like fruit, fresh. The peel of the fruit is stamped and mixed with other food to poison stealing dogs (Diriko)."

Marloth (1913-25: II: I: 120) and Engler (1912: 577) also refer to the edibility of the fruits.

There are four other plants of very similar appearance which could be confused with *Dichapetalum cymosum*, and although they were not collected on the expedition, their distribution does overlap. They are *Pachystigma pygmaeum, Pygmaeothamnus zeyheri, Parinari capense* and *Diospyros chamaethamnus*. The first two bear inedible fruits and may be

distinguished by their having opposite leaves. The latter two bear edible fruits and like *Dichapetalum* have alternate leaves. The differences are that *Parinari capense* has leaves dark green above and covered with a white felt below, and that *Diospyros chamaethamnus* has no stipules.

Another species, *Dichapetalum venenatum*, has been described, but is in my opinion not specifically distinct from *Dichapetalum cymosum*.

Ricinodendron rautanenii Schinz (5336) Photograph 25.

Eastern !khũ Bushman ,||k"a:

The trees seen on the expedition were about 25 feet high and were then (at the end of August) quite bare, resembling slender baobabs, with similar but thinner stems, and smooth bark and stubby branches. Specimens collected elsewhere showed that the leaves are digitately compound, with about five leaflets and two prominent green glands at the top of the leaf-stalk. They are dark green above and pale below and covered with a pale to brownish powdery wool which is found on the young twigs and fruits also. The trees are either male or female. The small creamy flowers are borne in bunches towards the tips of the twigs and the female flowers give rise to reddish fruits the size of a small plum, consisting of a thin pulp surrounding a very hard nut. This is light coloured like an almond, thick and strong and marked all over with numerous small pores.

The only trees seen were on heavy sand near the banks of the Eiseb omuramba, 29 miles from Gam on the way to Windhoek, where they were dominant in a belt several miles wide. They formed a woodland, with the trees spaced about 25 yards apart. Herbarium records show that this is the usual mode of occurrence. The species has been recorded from South West Africa, the Bechuanaland Protectorate, Rhodesia and Portuguese East Africa.

The pulp of the fruit is edible raw or stewed. It does not readily go bad, but in time it dries and shrivels and in this condition, turned hard and crumbly, is still a wholesome food, edible raw or cooked. The stone contains one or two firm white-fleshed kernels which are, like the pulp, edible raw or cooked. The tree is an important source of Bushman food because of the quality and quantity of its fruit and because the fruits remain good for a long time even without being stored. Those seen on the expedition were on the ground beneath the trees and were still perfectly good to eat. The tree is additionally useful in that it sometimes collects and holds rain water in hollows in its trunk (see Adansonia).

Sclerocarya caffra Sond. (5292) Photograph 26.

Eastern !khũ Bushman -gɑi

A few mature specimens were seen, about 20 feet high, and a few young ones. The mature trees had a single clean bole with a flaking bark and a branching rounded crown, and were very different in appearance from the young ones which consisted of four or five thick and sappy unbranched stems about five feet high, with a smooth brown bark. This was in August, and all were quite leafless. The following description is taken from Codd (1951):— "The leaves are pinnate with three or four pairs of well-spaced leaflets and a terminal leaflet. The leaflets are oval, smooth, tapering to an abrupt point and are about one and a half inches long and one inch wide. Flowers are inconspicuous and are produced in small sprays just before the appearance of the young leaves, some trees

being predominantly male and others mainly fruit-bearing. The edible fruits are somewhat oblong in shape about the size of a small plum, consisting of a firm skin, pale yellow when ripe, enclosing a large hard kernel, to which adheres a soft whitish, fibrous flesh, with a sweet-acid refreshing flavour."

These trees are recorded from tropical Africa southwards as far as Pretoria and Natal, but they were not seen along the route of the expedition south of Nama Pan. They were growing in sandy soil in fairly thick mixed bush.

Sclerocarya is well known as a wild fruit-tree throughout this range, and the fruits are eaten by many different animals as well as by man. They fall when still immature, but ripen quickly on the ground and become strongly aromatic. The Bushmen make use of the fruit after the pulp has been eaten or has rotted away, for the stone which remains contains a little oily flesh with a pleasant nutty flavour. However, as the stone is very hard and makes up 90 per cent of the whole, the labour involved in smashing it and extracting the flesh is considerable. The Imperial Institute, which investigated the stones to see whether the oil could be produced on a commercial scale, concluded that such a scheme would not be worth while.

Lannea edulis (Sond.) Engl. var. *glabrescens* Engl. (5185) Photograph 27.
Eastern !khũ Bushman gaga-ʃɛ

A plant with a thick underground trunk, from the crown of which arise a number of thin stems a few inches high, bearing 12-inch compound leaves. The leaves seen in the field had all been killed by frost but had not fallen although it was at the end of winter. They had a stiff, papery texture and appeared completely glabrous to the naked eye, but a few stellate hairs could be seen along the veins when the leaf was put under the lens. The following notes on the fruits are taken from the pamphlet by Verdoorn (1938:22):— "The ovary has four erect styles the remains of which can be seen as four little points on the mature fruits. The fruit which is only about half an inch long, is scarlet until it ripens, at which stage it turns purplish black. There is only a small amount of flesh but it is juicy and pleasantly sour. The stone is just over a quarter of an inch long, oblong and laterally compressed with the surface somewhat pitted."

One specimen was found during the expedition, growing in open woodland on sandy soil near Nama Pan, but the Bushmen stated that it becomes more frequent towards the north. It is widespread through the northern Transvaal and occurs in Southern and Northern Rhodesia as well as the Bechuanaland Protectorate and South West Africa. The glabrous form is rarer than the form with hairy leaves.

It is quite well known throughout its range because of its edible fruits, but it appears to be a rather sporadic bearer.

Rhus commiphoroides Engl. and Gilg (4889).

A semi-deciduous spreading shrub up to six feet in height with rigid branches and downy twigs, many of them spine-tipped. The leaves, which are also downy on both surfaces, are borne on a stalk a third of an inch long and consist of three obovate leaflets, toothed in the upper half and dull green. The minute flowers are greenish and inconspicuous and in lax sprays at the ends of the branches. The fruits are borne in clusters and are a quarter of an inch long and kidney-shaped. They are dry and have a papery brittle skin which is purple with glaucous bloom.

The plant was uncommon along the route of the expedition although it has a wide distribution from the northern Cape and the Transvaal through the Bechuanaland Protectorate to South West Africa and Southern and Northern Rhodesia.

The fruits are edible. They have a sour taste and a strong aroma and little more than that for they consist mainly of the skin and the stone. The leaves are sometimes used by the Bushmen for flavouring meat.

Ziziphus mucronata Willd. (4873, 5202) Photograph 28.

!hɔ̃: Bushman.....	!e:i
ǁganakwe Bushman...	ˌǁaja
ǂgikwe Bushman.....	≠k″erɔ
Naron Bushman.....	≠k″aru
Eastern !khũ Bushman	ˌn≠a:

A semi-deciduous shrub or tree up to 12 feet high, twiggy and profusely branched, with the older branches drooping at the ends to give it a rounded shape. As a rule it is very thorny, with the thorns in pairs, of which one is hooked and the other straight. Thornless specimens have been reported, but are rare, and none were seen along the route of the expedition. The plant has alternate dark green shiny toothed leaves, tapering to a point at the tip and with three or four prominent veins branching from near a rounded base. They are stalked, and glabrous or nearly so. The flowers are in small greenish clusters and are not conspicuous. The fruits are ripe in early winter, but the trees bear sporadically and the crop varies greatly in quantity in individual trees. The fruit is brown and a third of an inch in diameter, with a shiny brown papery skin surrounding a thin layer of rather dry, mealy substance and a large stone.

This tree is widespread from the Sudan to the Cape Province. It was uncommon on the deep Kalahari sand but fairly frequent in the hard soil round the edges of the pans, where it sometimes formed open communities.

The mealy substance in the fruits is sweetish and is eaten by the Bushmen, but it is not pleasant even by their standards.

Grewia avellana Hiern (4959, 5269) Photograph 29.

!hɔ̃: Bushman.....	n!ɔ≠udi
ǁganakwe Bushman...	n!ɔ≠udi
ǂgikwe Bushman.....	ǁgam-tsa
Naron Bushman.....	dʒudʒubu
Eastern !khũ Bushman	dzwa:ma and zɔ:ma

Because of its habit, this one of the few Grewias distinct from the many which look alike. It occurs as a number of slender erect 18-inch stems in patches a yard across, bare in winter except where sheltered from the frost. It has also been recorded as a shrub four feet high. In summer the stems are leafy enough to trap the wind-blown sand, so that they are usually found growing up through a slight hummock. The leaves, borne on very short stalks and measuring one and a half inches by an inch, are alternate, serrate, roughly hairy, prominently veined and dull green. The flowers have narrow white petals and are half an inch across. The fruits are a shiny dark brown, half an inch in diameter and characteristically lobed, being known in Sechuana by a name which means *the buttocks of the queen.* Only a few specimens were found in fruit, which suggests that the season was over by the time the expedition started from Molepolole (mid June).

The plant was widely distributed along our route, sometimes in the open grassland and sometimes in the belts of woodland, but was not common. It has been recorded from Angola, South West Africa, the Bechuanaland Protectorate and the Transvaal.

The fruits are edible but not very palatable, for they consist of large stones and only a little pulp, sweet and slightly mucilaginous. Nevertheless, according to a note on one of Schoenfelder's specimens (Schoenfelder No. 8, in the National Herbarium) they are a staple food not only of the Bushmen but also of several Bantu tribes, and can be kept when thoroughly ripe.

Grewia flava DC. (4941, 5024) Photograph 30.

!hɔ̃: Bushman..... ˌn‖a:
‖ganakwe Bushman... ˌk″um
ǂgikwe Bushman..... ˌk″wam
Naron Bushman..... ˌk″um
Eastern !khũ Bushman ˌnǀŋ

A rigid shrub about five feet high with numerous erect straight stems, often branching below the soil and so appearing unconnected. They are softly hairy when young. Old stems have a smooth dark bark and are sometimes slightly angled. The serrate leaves, which are shed in winter, are dull gray-green above and covered with a fine silvery down below, and make an attractive background for the bright yellow flowers which come out in midsummer. The fruits are half an inch across, usually four-lobed, and brownish-yellow when ripe.

Grewia flava is known from the four provinces of the Union, and from South West Africa and the Bechuanaland Protectorate. It occurred nearly everywhere along the route of the expedition and was one of the commonest shrubs of the central Kalahari, but only one of all the thousands of plants seen was in fruit.

The fruits have a little edible sweet pulp surrounding the seeds. They are an important Bushman food, not so much because of their quality as because of their abundance, and because they can be kept if they are first dried. They are then soaked in water or cooked before being eaten.

Grewia flavescens Juss. (5053).

A lax deciduous shrub or scrambler up to 12 feet in height, with slender stems which often become four-angled in older specimens, and with leaves, flowers and fruits similar to those of *Grewia retinervis*. There was little of it fruiting, but whether the season was over or whether it is naturally not a heavy yielder is uncertain.

This species has a wide distribution through tropical Africa. It was not seen south of Ghanzi, but was scattered from Ghanzi northwards to Gautscha Pan.

Its fruits are eaten by the Bushmen. As most of the Grewias were leafless and as there were more species towards the north, it became increasingly difficult to estimate the frequency of each when once the Ghanzi area had been passed, and nothing can be said as to the relative importance of the northern species in the Bushman diet.

Grewia retinervis Burret (4875, 5066) Photograph 31.

!hɔ̃: Bushman.....	⊙bɔ̃:
ǁganakwe Bushman...	ǁ?ani
ǀgikwe Bushman.....	ǁgani
Naron Bushman.....	ǁgani
Eastern !khũ Bushman	!gwa

A straggly many-stemmed five-foot shrub, sometimes a weak scrambler up to 10 feet high. The stems are half an inch thick at the base, rounded and slightly woolly when young, slightly flattened and glabrous when old, and tough and pliant. Its leavers are alternate, pale green, one and a half inches long and an inch wide, ovate with a pointed tip, toothed, and roughly hairy to the touch. They wither and fall soon after being frosted, but if out of reach of the frost remain on the bushes at least until the end of July. The plant bears spreading yellow flowers half an inch wide, and fruits the size of a pea, with a papery brown skin enclosing a few large pips and some fibrous mealy material. *Grewia retinervis* is closely allied to *Grewia flavescens,* so much so that I doubt whether the two should be considered anything more than varieties of one species. The differences are that *Grewia flavescens* is usually taller, and not so conspicuously veined on the upper surface of the leaves. Mr. B. de Winter, of the National Herbarium, Pretoria, has observed also that its older stems are square in section and those of *Grewia retinervis* are flattened.

Grewia retinervis was scattered over most of the area covered by the expedition, and common in the central Kalahari, specially in open grassy country. It has been recorded from the northern Cape and the Transvaal as well as South West Africa and the Bechuanaland Protectorate.

The fruits are edible. They ripen in winter, and have a slightly sweet taste and a pleasant flavour. They may be stored after being dried, and are then soaked or boiled before being eaten. The crop, if one may judge from the 1955 season, is abundant, and the amount fairly constant for all the bushes. The fruits form an important part of the Bushmen diet, although little of them appears digestible. The roughage is voided almost unchanged, in enormous faecal masses up to two and a half inches in diameter.

The dry stems of this plant nearly always contain the tunnelings of grubs, and the tunnellings are packed with their excreta in the form of a brown, pith-like substance which forms a useful tinder. The Bushmen split the stems down the centre, make a slight depression in the flat surface and use this as a socket for the fire-drill.

Grewia sp. aff. *Grewia bicolor* Juss. (5056).

Eastern !khũ Bushman gamak″wɔ:

A slender shrub up to six feet high, with many sparingly branched stems. The leaves are one and a half inches by one inch, very finely toothed, dark green above and pale below, pointed at the tip and rounded at the base. Both surfaces are covered with a fine grayish felt which is thicker on the lower surface. Typical *Grewia bicolor* has wool on the lower surface only. The fruits are the size of a pea, and have a little flesh covering usually one big seed. No flowers were seen.

This is another of the plants with a distribution which begins in the Ghanzi area and extends northwards, and the remarks made as to the distribution and importance of *Grewia flavescens* apply here also.

The fruits are edible.

Adansonia digitata L. Photograph 32.

Eastern !khũ Bushman ≠m

The Baobab, as it is commonly called, is shown in photograph 32. Its stem may have a circumference of up to 148 feet, and makes it quite unmistakable. In winter it is leafless but in summer it bears dense dark-green foliage. The flowers are pure white and up to six inches across, and the fruits, as described by Codd (1951: 120) are "oblong or egg-shaped, five to six inches or more in length and three to four inches in diameter, with a woody shell which is softly grey-velvety on the outside".

The southernmost specimens were seen in the neighbourhood of Ghanzi, and from there it occurred sporadically to Gautscha Pan, the furthest point north reached by the expedition. There were big gaps in its distribution and it was rare throughout, but in some parts of the Transvaal it occurs abundantly and may have an unbroken distribution over many square miles of country. It is widely distributed in the drier regions of north and south tropical Africa.

Inside the shell of the fruit is a white, pith-like substance which may be eaten raw, or ground up and stirred into water to make a drink, or boiled to make a porridge. It has an acid-sweet taste. The seeds which are embedded in the flesh are also edible and are eaten like nuts. In other parts of Africa they are prepared in a somewhat involved way which includes protracted boiling, fermenting and drying. There are several records of the fact that the young leaves make quite a good substitute for spinach, but as the expedition was during the winter and as the trees are deciduous, I cannot say whether the Bushmen know of this, nor whether the trees we saw were of the glabrous variety which is the one used for spinach. No seedlings were seen. It is known that the white shoot from the germinating seed can be used as a substitute for asparagus, and that the tender root of the very young Baobab is also edible (Dalziel, 1937: 113). The trees are often hollow, and like *Boscia albitrunca* and *Ricinodendron rautenii* may act as reservoirs for rain water which can be used in times of scarcity. The Bushmen reach it by fitting hollow grass stalks end to end to form a tube, and sucking it out. A further product of the Baobab is a large caterpillar which feeds upon the leaves and which is an important article of food aming the Natives of the northern Transvaal. It is recorded also from South West Africa, and is very likely known to and used by the Bushmen.

Ochna pulchra Hook. (5273) Photograph 33.

Eastern !khũ Bushman !i and !e:i

A semi-deciduous tree with a clean but usually rather twisted bole which is white to light gray and has a peeling bark. The branches are bent and rigid and the wood brittle. They bear glossy light green alternate leaves which are almost sessile and usually entire, rarely with a very finely toothed margin. The tree has an attractive appearance even in winter, and the young leaves add to this in the spring for they range from pale green to reddish-brown. The flowers are borne in early summer, in showy scented bunches. They have yellow petals and a green calyx, which persists after the petals have fallen and turns bright red. The fruits are hard and green when immature but turn fleshy and black as they ripen. There are usually two or three, the size and shape of small beans, attached to a fleshy red swelling in the centre of the flower. The leaves have been suspected of causing poisoning in stock, but tests carried out on mammals have so far been inconclusive. (Uys and Thomas 1952, Steyn, 1949: 125.)

Ochna pulchra is well known and widely distributed from the Transvaal to Northern Rhodesia and Angola. It was frequently seen in southern Bechuanaland and again in the north, but there was a gap between of about 200 miles where it was not recorded. Ghanzi was approximately in the centre of this gap. In the parts traversed by the expedition it was seen growing only on deep sand or in rocky soil.

The Bushmen stated that the ripe fruits when boiled in water yield a fat, which can be skimmed from the surface and used as food. This is confirmed by the notes on the specimen collected by E. B. W. Schoenfelder (number 28):—

> "Fruit when still green eaten after roasting in ash (Kung). When black and ripe cooked with water and the fat skimmed and preserved. The cooked fruit is eaten with pips (Kung and Diriko)."

Combretum apiculatum Sond. Photograph 34.

Eastern !khũ Bushman ǁaja

A small tree or many-stemmed shrub, usually about 10 feet high in the drier areas. It has paired rather stiff pale green glabrous leaves with a varnished appearance, which turn yellow in the autumn and persist on the tree well into the winter before being shed. The flowers are small and greenish-yellow and would be insignificant except that they are numerous and massed at the ends of the twigs. The fruits have four papery wings and are about an inch in diameter.

Combretum apiculatum is widespread and often common, extending from Northern and Southern Rhodesia through the Bechuanaland Protectorate to South West Africa and through the northern Transvaal to Natal, but it was not seen along the route of the expedition until the Gautscha Pan area was reached, where it occurred sparingly.

The Bushmen stated that it produces an edible gum. I have been able to confirm this in the Transvaal, but observed that the gum is produced only rarely.

Combretum coriaceum Schinz (5052, 5270, 5330).

Eastern !khũ Bushman ≠gwa

An evergreen tree with paired stiff gray-green leaves. It is usually rather erect and in these parts seldom more than about 10 feet high, though it grows up to 30 feet under moister conditions in the northern Transvaal. The flowers appear towards the beginning of September. They are yellowish in colour and small, but crowded into showy little masses towards the tips of the twigs. The four-winged fruits are reddish-brown, and dry and papery.

It has been recorded from tropical Africa southwards to the Transvaal and Natal, but under a variety of names. Along the route from Molepolole to the north it was first seen 67 miles before Ghanzi. From there to Gautscha Pan it was fairly common except in the neighbourhood of Lake Ngami and the Okavango swamps.

Although the tree produces an edible gum, it does so too rarely to be of importance as a food supply.

Combretum imberbe Wawra (5204) Photograph 35.

Eastern !khũ Bushman ≠ɔ

There were some magnificent specimens of this tree seen on the expedition, up to 40 feet in height, but the average was about 20 feet. It is rather sturdy as a rule, with a clean bole and light gray bark which is deeply fissured in all directions, and rigid branches and twigs. When young these are opposite or sub-opposite, straight, and often tipped with a hard spine, but as they grow older the spiny character is lost and the growth form becomes crooked so that the symmetry is masked. The tree has small opposite gray leaves an inch long and half as wide, and like the other species of Combretum it bears four-winged fruits and small inflorescences of yellowish flowers.

It was frequently seen in the Ghanzi area and to the north of Ghanzi, but not to the south, although it has been recorded from as far south as Vredefort in the Orange Free State. Its range is from Natal and the Transvaal through to tropical Africa.

It exudes an edible gum, but only rarely.

Terminalia sericea Burch. Photograph 36.

Eastern !khũ Bushman -dzɔ and za-ɔ

Sometimes a graceful, erect, 30-foot tree with horizontal branches and a dark gray fibrous bark, and sometimes a much-branched shrub two or three feet high. The twigs tend to curve upwards slightly and bear towards the tips bunches of soft alternate leaves three inches long and an inch wide, darker on the under surface and covered with a fine silvery down. The tree is seldom completely deciduous, and many of the fruits also remain on the twigs through the winter. They are reddish and consist of a flattened seed with a wide membranous margin which forms a wing and aids their distribution through the wind. The flowers are borne in creamy catkins and have a strong and rather offensive smell. Another characteristic feature is that the twigs often have walnut-sized galls round them.

This species was common all along the route of the expedition, and has a wide distribution from east and west tropical Africa to the northern parts of the Cape Province and the Transvaal. It is usually on deep sand, and usually in communtities.

It sometimes produces an edible gum from injuries in the stem.

Royena sericea Bernh. (5018, 5249).

A many-stemmed deciduous shrub up to six feet high, with a dark bark and crooked branches. The dull green leaves are obovate, sometimes pointed, alternate, velvety when young, usually one inch by half an inch but sometimes much smaller, and they tend to be crowded towards the tips of the twigs. Its flowers are creamy, inconspicuous but scented, with the petals tightly furled in the bud. The fruits are half an inch long, ovoid and with a smooth skin which turns red when the fruits are ripe. They contain several large seeds and a little yellowish pulp.

This shrub was widely scattered north of the Ghanzi area and rarer still to the south, where only one small clump was found.

No information was obtained from the Bushmen about it, but the pulp of the fruits is known to be edible and would no doubt be used in an emergency. It is faintly sweet, and insipid.

Strychnos cocculoides Bak. (4916) Photograph 37.

ǁganakwe Bushman... ,ǀguwa

A 15-foot tree, erect and rather slender, sometimes unarmed and sometimes with very sharp paired curved thorns a little less than half an inch long. The leaves, which are also paired, are soft, minutely hairy and an inch and a half long and an inch wide with three prominent veins branching from near the base, one central and two near the margins. The old bark is dark gray, corky and deeply fissured, but the young twigs have a smooth bark densely covered with a fine down. The tree produces small greenish flowers massed into heads three quarters of an inch in diameter. The fruits are a little over a pound in weight and four inches in diameter, the size and shape of a gem squash, with the same type of hard rind, green when immature and turning pale brown when ripe. The seeds inside are embedded in a strongly aromatic pale pulp.

Strychnos cocculoides is recorded from the western Transvaal, the Bechuanaland Protectorate, Angola and central tropical Africa. On the expedition it was seen scattered through only one belt of heavy sand which began 136 miles north-west of Molepolole and ended 35 miles further on.

The fruits have an unusual and pleasant flavour, and according to a note on one of Schoenfelder's specimens in the National Herbarium the seeds may be eaten as well as the pulp. Galpin (1925: 22), who describes this tree under the name *Strychnos schumanniana,* states that the fruit may be picked green and ripened by burying it in sand. It will keep for several months without going bad.

Strychnos pungens Solered. (5447) Photograph 38.

An eight-foot bent evergreen tree with a spreading crown and paired hard shiny leaves with a sharp spine at the tip. It bears insignificant greenish flowers in compact small bunches in the axils of the leaves. The fruits and the veins in the leaves are similar to those of *Strychnos cocculoides,* and it has the same general distribution. Only one specimen was seen, near the northermost point reached by the expedition.

The fruits contain a pleasant edible pulp which is, however, not considered as good as that of *Strychnos cocculoides.*

Raphionacme burkei N.E. Br. (4997) Photograph 39.

!hɔ̃: Bushman..... bi:
ǁganakwe Bushman... bi:
ǀgikwe Bushman..... bi:
Naron Bushman..... bi:

Nearly all of the plant is six inches below ground, in the form of a rounded storage organ about five pounds in weight and six inches in diameter, slightly flattened on top. It has a brown skin, and is pale yellow inside with flecks of white latex on the cut surface. It is connected by a "neck" a little thicker than a pencil to the above-ground parts, which consists of a few sparingly-branched erect stems, slender but wiry, six inches high and bearing narrow grayish-green leaves. The flowers, which are borne in small clusters, are greenish and inconspicuous. the fruits slender, three inches long and as a rule in pairs. The stems exude a milky juice when injured. They are not easily seen even in summer, and in winter less so, for the leaves are shed and the stems die back.

By the spring there may be nothing left to mark the position of the plant. How extraordinarily observant the Bushmen are was well shown when they were asked if they could find a specimen and demonstrate its use. One man guided the party for four miles across country featureless except for clumps of trees to a spot where he knew of one growing. It was found after a short search—nothing more than two or three small sticks among the grasses, with the bark shredding into white silky fibres.

Raphionacme burkei is found from South West Africa through the Bechuanaland Protectorate into the northern Transvaal and the northern Cape. Two specimens were seen in the central Kalahari, and the species was determined from one of them which was sent to Pretoria for cultivation and flowered there in the following summer.

It is a well-known source of water among the Bushmen of the Kalahari. They extract the water from the storage organ by planing a pile of shavings off it with the edge of a split stick, and then squeezing the shavings in the hand and allowing the water to run into the mouth. This rather roundabout way of doing things appears to be without good reason, because the flesh of the storage organ may be chewed without any ill effect. It is firm and crisp, slightly fibrous, and faintly bitter.

Pentarrhinum insipidum E. Mey. (5171, 5191) Photograph 40.

Eastern !khũ Bushman n!ɔ-ʃu and n!wa-ʃu

A leafy deciduous climber up to 10 feet high, and a vigorous grower which may completely cover the host tree. It has freely branching lax stems which are quite tough in spite of being only a matter of an eighth of an inch in thickness. They are covered with a fine white down which is just perceptible to the naked eye, and when broken they exude a little milky juice, so little that it is easily overlooked. At intervals of about five inches arise pairs of leaves, deeply cordate at the base, and with long stalks. In the younger stages they are minutely hairy but they become glabrous or nearly so as they grow older. The flowers rise in a group on a three-inch slender stalk from between the leaves. They are brownish with a yellow or white central portion, small and faintly scented. The fruits are occasionally produced in pairs but are more usually solitary. They are beaked, three inches long and half as wide, covered with blunt prickles, longitudinally wrinkled and dull green.

At Nama Pan this was a frequent climber among the trees, and it is widespread over southern Africa. It was not, however, seen in the country south of Ghanzi.

At maturity the fruits are hard and woody and packed with the fine silky hairs that form the pappus of the seeds, but when green they are softer and may be eaten raw or cooked as a vegetable, and may be stored for three weeks before they deteriorate. Their rather copious white latex is quite harmless. They have a crisp texture when raw and a pleasant flavour, nutty and faintly peppery. When boiled they are reminiscent of Asparagus. When the seeds inside have turned brown the fruit will be found too hard to make good eating. The leaves, too, may be eaten raw as a salad, and are used that way by some Transvaal Natives, but the Bushmen method of preparation is to pound them to a pulp in a wooden mortar.

Pentarrhinum insipidum grows well from seed and is a rapid producer of green material. It might be a useful fodder plant for domestic stock.

Sarcostemma viminale R. Br. (4993, 5170) Photograph 41.

Eastern !khũ Bushman !gubu!gubu

A leafless climber, reaching a height of 10 feet or so, with gray-green jointed branching stems as thick as a pencil and containing a large quantity of pure white latex. They bear yellowish strongly scented flowers, and fruits shaped like a slender carrot. The plant is occasionally found growing in the open, away from any support, in the form of a dense clump of ascending stems about three feet high.

It is widespread in South West Africa and the Bechuanaland Protectorate, and through the drier parts of all four provinces of the Union.

There are records from the Cape Province, Natal and the Transvaal that the stems and fruits of this plant are eaten by the Natives, either cooked as a vegetable or raw as a salad, and I have eaten the raw stems in the Cape Province. They have no distinctive flavour. It is a dangerous plant to eat, for there is a poisonous strain of it which is not visibly distinguishable from the edible one (Dyer, 1937: 123), and which, if eaten in sufficient quantity, causes death after symptoms like those produced by strychnine. The Bushmen said that they never used it for food. I have no information as to its use or otherwise in the central Kalahari, where it also occurs. Presumably it would be safe for food where browsed by animals, which often happens and is easily seen.

Ceropegia tentaculata N.E. Br. (5220) Photograph 42.

!hɔ̃: Bushman..... ǁala
Naron Bûshman..... !ʔaru
Eastern !khũ Bushman !ama

A twiner up to eight feet high, minutely hairy, with opposite almost fleshy leaves about an inch long rising at intervals of two to three inches. The flowers which are produced on short stalks in a group of half a dozen or so are three quarters of an inch long and tubular, with a swollen base and lobes at the top produced into slender threads. The fruits are paired, four inches long, very slender, gray and filled with seeds attached to a silky pappus. The plant has a tuber a few inches below the surface of the soil, the size of a flattened apple, with a distinct hollow at the top from which the stem rises and with a rounded base which produces many short and slender roots. It is the colour of a new potato.

Ceropegia tentaculata has seldom been collected, and is recorded only from South West Africa. One specimen was found growing in deep sand in the shelter of a thicket about twenty miles south-west of Nama Pan. As it was recognised and named by one of the !hɔ̃: Bushmen who was with the expedition in South West Africa, it probably occurs also in the Bechuanaland Protectorate in the southern Kalahari, which is the home of these people.

The tuber is edible when roasted.

Ceropegia sp. near *Ceropegia leucotaenia* K. Schum. (5309) Photograph 43

Eastern !khũ Bushman |gwi-ts'ou

The above-ground parts are pubescent, otherwise similar to those of *Ceropegia tentaculata*. The flowers also arise in groups but have a shorter tube, about half an inch long, with the processes of the lobes connected at the tips. The processes are dark brown and covered with slender hairs.

The plant has a shallow tuber which is about as big as a billiard ball but bell-shaped, with fine roots sprouting from the flattened base. It is similar in colour to the tuber of *Ceropegia tentaculata*.

Only one specimen was collected, in the shelter of bushes on sandy loam near Nama Pan. It was cultivated in Pretoria and flowered in January, 1956.

The tuber is edible when roasted.

Ceropegia sp. near *Ceropegia lugardae* N.E. Br. (5264) Photograph 44.

Eastern !khũ Bushman n!wi:

In the above-ground parts the plant is like No. 5226 (*Ceropegia* sp. near *Ceropegia mozambicensis*), but it is more leafy and the flowers have a single instead of double swelling at the base. It has a similar bunch of pencil-shaped roots.

One specimen was collected in shallow sand overlying rock at Nama Pan. It flowered in cultivation at Pretoria at the end of March, 1956.

The roots are edible when roasted and in texture and flavour like those of No. 5226.

Ceropegia sp. near *Ceropegia mozambicensis* Schltr. (5226) Photograph 45.

!hõ: Bushman..... ˌgu:ǂn‖a
Naron Bushman..... ˌgu:ǂn‖a
Eastern !khũ Bushman ǂn‖ßama

A twiner with very sparsely hairy stems and leaves similar to those of *Ceropegia tentaculata*. The differences are that the flowers are borne in pairs on a peduncle about one inch long, one flower maturing long before the other, and that the flowers have a double swelling at the base and at the top are broadly funnel-shaped, with erect folded dark brown broad lobes connected at the tips and edged with sparse hairs. The tube is greenish, spotted with purple. The stem arises from a bunch of pale fleshy roots about six inches below the surface of the soil, the size of pencils but tapering at the ends and constricted at the top so that they are easily broken off.

Only one specimen was seen. It was growing in the shelter of a thicket on deep sand about 20 miles south-west of Nama Pan. It flowered in cultivation in Pretoria in January 1956.

The roots are edible when roasted. They taste somewhat like a potato, but are firmer and have a flavour of their own. They have no fibre and the plant would be worth investigating for improvement and cultivation as a vegetable.

Duvalia polita N.E. Br. (5187) Photograph 46.

Eastern !khũ Bushman ǂda:daba

A sprawling succulent plant. The fleshy stems are glabrous, uniformly gray-green and four inches high, with usually six longitudinal rows of soft spines with a deep crease between each row. They rise from underground runners which are white and lack the distinct spininess of the stems. The corolla-lobes surround a prominent fleshy basal ring, and are dark brown, sometimes with vibratile hairs similar to those of *Caralluma knobelii* and sometimes irregularly flecked with yellowish-green. The

specific name, which means *polished,* refers to the shiny appearance of the corolla-lobes towards the base. The fruits, borne in pairs, are between a half and a quarter of an inch in thickness and six inches long, tapering at the end and containing numerous flattened seeds with a silky pappus.

Although it has a wide range across tropical and sub-tropical Africa, it is uncommon, and only one specimen was collected on the expedition, under the shelter of scrub at the edge of a rocky outcrop at Nama Pan.

The stems are edible raw or roasted, but have a bitter taste. They are sappy enough to be a useful source of water.

Caralluma knobelii (Phill.) Phill. (5094, 4914) Photograph 47.

!hõ: Bushman..... -≠abɛrɛ
‖ganakwe Bushman... -da:daba
|gikwe Bushman..... -da:daba
Naron Bushman..... -da:daba
Eastern !khũ Bushman -da:daba

The plant consists of a number of stubby, succulent erect stems four inches in height and half an inch in diameter. They are glabrous and dull bluish-green, mottled faintly with a darker green and square in section, with four rows of sharp and fairly hard-tipped spines. They exude a clear greenish juice when cut. The flowers are white to greenish, with dark purple blotches and edged with sparse delicate knobbed hairs known as vibratile hairs because of the way they are moved about by even the gentlest breeze. The stems arise from underground runners which have the same form as the erect stems except that they are white, and more slender.

This species, which is known only from the Kalahari, was found in various places on deep sand between Molepolole and Ghanzi, but was nowhere common. It was in the shelter of trees and scrub, and was not seen in the open.

The whole plant is edible raw or roasted, but the underground portions are better than those above ground, which tend to become bitter. They have a peculiar smoky flavour which is not unpleasant, and their abundant juice makes them a useful source of water.

Stapelia kwebensis N. E. Br. (5140) Photograph 48.

Eastern !khũ Bushman -da:daba

Similar in habit to *Caralluma knobelii,* but with dull green downy stems and rounded instead of sharp corners. The spines too are shorter and tipped with small erect leaves. It has dark brown flowers with slender lobes ridged on the upper surface and radiating out from a shallow central pit.

Only one specimen was collected on the expedition, on a rocky outcrop at Gam, but the species is widely distributed in South West Africa except in the extreme south and it is known from the northern Transvaal as well.

The stems are edible, raw or roasted.

Fockea sp. (5136, 5236).

Eastern !khũ Bushman ′!xwa:

One of the two specimens collected was in the open among rubble at the edge of a sheet of rock at Gam, a plant with fleshy stems 12 inches high, and the only one of its kind seen in that vicinity. The other specimen was growing with several more in stony scrub-covered ground near Gautscha Pan, and appeared similar except that the stems were thicker and were twining to a height of several feet among the other bushes. The

leaves drop during the winter, but a few were still to be seen, linear, paired, and about three inches long and half an inch wide, and there was one fruit, as long as the leaves and shaped like a small cigar. The stems rise from a brown-skinned underground storage organ which may be more than a foot in length and up to five inches in diameter. It is often oddly shaped if growing in rocky ground, as these all were, and has a rather spongy texture, a combination which makes it difficult to dig up without damage. Several were brought in at a Bushman encampment about 20 miles south-west of Nama Pan, but none of them were entire. The specimens I collected were lost in transit to Pretoria, and though they could be placed in the genus Fockea from what had been seen in the field, the species is unknown.

The storage organ is eaten raw by the Bushmen. The flesh is white and rather flabby, with a faint but pleasant flavour of coconut ice. As well as being a food it is juicy enough to be a useful source of water. It could possibly be bred into a plant worth cultivating.

Ipomoea verbascoidea Choisy (5223, 5319) Photograph 49.

Eastern !khũ Bushman n!ɔru

Tubers and seeds of this species failed to grow in cultivation in Pretoria. The notes which follow were made partly from herbarium specimens, for the plants were quite leafless when they were seen in the field in August. They were conspicuous in spite of their bareness, because of the small pure white masses of wool in which the seeds were embedded. These masses were scattered along numerous slender twigs that arose from a group of sturdy, cane-like stems, half an inch thick and eight feet long or more. The stems are scramblers, or, if no trees are at hand, lax and spreading. They exude a little milky juice when cut. The stalked leaves are simple, rounded, and up to four inches across, and bear in their axils single large purple flowers of the typical Convolvulaceous (morning glory) type. The plant is covered with a white wool except on the upper surface of the leaves, where it is sparsely hairy.

Two plants were seen on the expedition, both in the neighbourhood of Nama Pan, and both on sand and among fairly dense mixed scrub. There are records of the species from South West Africa, the Bechuanaland Protectorate and Angola.

A note on one of the herbarium specimens states that the fruits are edible, but this was not mentioned by the Bushmen. They did however state that the storage organs were used as a source of water. These are six inches below the soil, sometimes partly exposed and partly eaten by animals. They are firm and juicy, and those seen were the size of a football, with a white flesh and a dark brown skin. The water may be extracted by chewing the flesh or by pounding it and squeezing the pulp.

Ipomoea sp. (5179) Photograph 50.

Eastern !khũ Bushman !garubɛ

A slender plant with three or four bluish-reen leaves up to three inches long, borne on a four-inch erect stalk and themselves erect, and deeply and narrowly lobed. There are usually three or four tubers to each plant. They are found at any depth down to nine inches, and are variously shaped but regular in outline, typically the size and shape of a large apple with a slight depression on top, where they are connected at intervals of

a foot or so to an underground stem which branches and turns unexpectedly in various directions. They have a thick brown skin with a bronzy sheen, are slightly bitter to the taste and exude a little latex when the skin is broken. No flowers were seen in the field, and although specimens cultivated in Pretoria made good growth, they did not produce flowers. No fresh leaves were seen in the field either. They are evidently very susceptible to the cold, for it was noticed that the cultivated specimens dropped theirs before the first frosts.

Fragments of this plant which had been killed by frosts were scattered plentifully through the open grassy sandy areas near Nama Pan, and the tubers were often unearthed while other plants were being dug up.

The Bushmen stated that they did not eat the tubers, but that they were eaten by buck.

The leaves of this plant cannot be distinguished from the leaves of *Ipomoea bolusiana*. *Ipomoea bolusiana* is known to have an edible tuber (Schinz, 1888: 271, Boss, 1934: 87), and from the available herbarium specimens and the literature it appears that it is single, and immediately below the surface of the ground. Because these two facts are in conflict with what was seen and what was reported by the Bushmen, it is doubtful whether the plant from Nama Pan is the same species.

Ehretia rigida (Thunb.) Druce Photograph 51.

!hɔ̃: Bushman.....	ǁga
ǁganakwe Bushman...	ǁgawu
ǂgikwe Bushman.....	ǁga
Naron Bushman.....	ǁga

A shrub, usually about six feet high, with a pale gray bark, a rigid, erect habit and a mass of branches, which in older plants spread out and turn downwards to give a "weepy" appearance. New growth is straight and smooth, and there is a very fine rusty wool on the youngest twigs. It contrasts strongly with the older growth, which is usually knobby and crooked and quite glabrous. The leaves are elliptic or obovate, stiff, minutely hairy and shortly stalked. They are scattered evenly along the new growth, but on the old growth they are crowded on dwarf shoots averaging an inch in length. Their dull green colour makes the plant rather unattractive, but it can become showy when the small blue or white flowers are out. The fruits are the size of a pea, soft and red when ripe and often with the withered remains of the style persisting.

Ehretia is found in all four provinces of the Union and in South West Africa, the Bechuanaland Protectorate and Rhodesia. It was scattered through the Kalahari south of Ghanzi but was not recorded in the north, and was never common and never gregarious.

The fruits may be eaten raw when ripe, but are insipid, with a sickly-sweet taste and a faint and rather unpleasant flavour.

Rhigozum brevispinosum O.Ktze. (4946, 5255).

!hɔ̃: Bushman.....	ˌǁha:
ǁganakwe Bushman...	nǀɔ-ji
ǂgikwe Bushman.....	ˌtʼa:
Naron Bushman.....	nǀɔ-ji

An erect, slender deciduous shrub up to 10 feet high, with opposite branches and opposite blunt spines which develop into branches like the spines of *Catophractes alexandri*. There is a small tuft of wool below each spine, from which is produced a bunch of six or eight leaves an

inch long and less than a quarter of an inch wide. No flowers were seen on the expedition, but from herbarium records it is known that they are yellow and tubular and produce papery pods two inches long and half an inch wide. The pods split down their centre when they are mature.

This plant is known from the northern Cape, the Bechuanaland Protectorate and South West Africa, and was widespread and fairly frequent north and south of Ghanzi.

Although it is not an edible plant it is nevertheless a producer of food, for all the Bushman digging-sticks seen were made from it. The only preparation is that the bark is peeled off, the spines trimmed, and one of the ends cut at a slant. The stick is about four feet long. In sandy soils and for the type of digging usually required it is a more efficient tool than a spade. It may be made to loosen a narrow cylinder of earth, and this cylinder, if a little wider than the object sought, is all that is necessary. With a spade on the other hand it is usually impossible to avoid a funnel-shaped excavation which entails the removal of far more soil.

Catophractes alexandri D. Don (4893) Photograph 52.

!hɔ̃: Bushman.....	n!ain!ai
ǁganakwe Bushman...	!ga:!gaba
ǀgikwe Bushman.....	ga:giba:
Naron Bushman.....	n!ain!ai

A five-foot erect silvery bush with opposite leaves, some brightly coloured in the autumn and winter. They often bear slender sharp spines in their axils, which afterwards develop into branches and bear leaves and spines in their turn. The leaves and younger woody parts are covered with a dense white wool, but this afterwards disappears from the woody parts and they become a reddish brown. The flowers, which are about two inches long, are white, trumpet-shaped and showy, and produce a pod covered with short blunt prickles and up to three inches long, dark and woody when mature and splitting down the centre. The seeds have a circular membranous wing round them.

The plant is recorded from Angola, South West Africa, Southern Rhodesia, the Bechuanaland Protectorate and the Transvaal. It was fairly frequent south and north of Ghanzi, in patches down the banks of pans, on limestone, and occasionally also on slight slopes in sandy country.

Catophractes alexandri is not a food plant but deserves mention because of its importance in the preparation of food—it is used as a fire-drill together with *Grewia retinervis*, as is described in the notes on that species.

Corallocarpus sphaerocarpus Cogn. (5020, 5138, 5230) Photograph 53.

ǀgikwe Bushman.....	ǀhurugu
Naron Bushman.....	ǀhɔrɔ
Eastern !khũ Bushman	ǀhɔrɔ

A very variable plant creeping by means of tendrils over shrubs and low trees, and with sparse leaves, dissected or lobed and rough to the touch, rising in groups or singly from nodes on the rather sappy stem. The leaves are not flat even when perfectly fresh, but inrolled slightly at the margins as though they were beginning to wilt. Three or four sessile half-inch ovoid fruits are borne in a cluster at the nodes as well, which in

older stems often form the points of characteristic zig-zags. The fruits are red when ripe and contain about five seeds. They open by means of a latitudinal break (circumscissile dehiscence) so that the skin at the end of the fruit comes off like a cap. The central jelly-like portion of the fruit, which has the seeds embedded in it, often remains behind when the cap is removed. The plant is deciduous, and the vine dies back if the winter is severe. It arises from a pale brown rootstock the size and shape of a large pear, which in the three specimens collected was partly above the level of the ground.

Its range is from the northern Cape Province, the Transvaal and Zululand through to Rhodesia and South West Africa. It was collected south of Ghanzi and again in the neighbourhood of Gautscha Pan, but was nowhere common. It is a woodland plant and does not occur in the grasslands.

The fruits are sweetish and edible when ripe. The rootstock is bitter and is not eaten, but the stems and leaves are boiled to produce a spinach which is fairly palatable, but stringy. It is eaten also by certain Natives in the northern Transvaal.

Corallocarpus welwitschii (Naud.) Hook. f. (5315) Photograph 54.

Eastern !khũ Bushman !gwara!ai

The fruits of this plant have a short but fairly distinct stalk, and its rootstock has a faint unpleasant smell when freshly dug. In all other respects it appears to be identical with *Corallocarpus sphaerocarpus.*

It has been recorded from the Bechuanaland Protectorate and South West Africa, but so far not from the Union. The only specimen found on the expedition was growing in sand under trees at Nama Pan. It grew well in cultivation at Pretoria.

There is no information on the edibility or otherwise of the vine, but the ripe fruits may be eaten raw. They are sickly sweet and flavourless. The Bushmen stated that the rootstock is edible after being cooked, but I found it too bitter to eat.

Momordica balsamina L. (4929, 4970, 5003) Photograph 55.

A climber over grass and low bushes or a runner over the ground, with sharply-lobed light green leaves about two inches across arising singly at intervals of a few inches along the numerous lax, slender stems. It has three-inch spiralling tendrils rising at the bases of the leaves. It is glabrous, with a soft, attractive look, but has a strongly unpleasant smell when bruised, The flowers are an inch across, pale yellow and after the usual Cucurbitaceous pattern as shown in the photograph of *Coccinia rehmannii.* The fruits, green when immature, are an attractive orange when ripe, one and a half inches long and an inch in diameter, with about ten longitudinal rows of short blunt prickles, and contain half a dozen seeds enveloped in a crimson pulp. The skin of the ripe fruit splits longitudinally and almost explosively when it is handled. The plant is an annual according to the *Flora Capensis,* but those in the Kalahari remained alive through the winter and put out fresh vines in the early spring to replace the frosted growth of the previous season.

It has been recorded from the four provinces of the Union and from Portuguese East Africa, the Bechuanaland Protectorate and South West Africa, and although it was not noticed north of Ghanzi, it was widespread to the south.

The fruit, according to the label on one of the herbarium specimens, is " very poisonous ", but there appears to be no satisfactory proof of this. The Bechuana state that the crimson pulp round the seeds is edible, and I ate it without any harmful effects. It is sweetish but has a rather unpleasant slimy texture.

Citrullus naudinianus (Sond.) Hook. f. (4983, 4984, 5272) Photograph 56.

!hɔ̃: Bushman.....	ǁgan
ǁganakwe Bushman...	gã:
ǂgikwe Bushman.....	gã:
Naron Bushman.....	gã:
Eastern !khũ Bushman	tʃa

This vine, commonly known as the Gemsbok komkommer, is a runner on the sand and not a climber. It has a tap-root the shape of a large carrot, which may be three inches or more in diameter at the top and three feet long, and which grows hard and woody with age. The younger roots are full of juice and intensely bitter, and cannot be eaten by human beings, although many showed signs of having been eaten by animals. The runners, which may reach a length of 30 feet, are stouter than those of the related *Cucumis hookeri* and No. 4895 (see page 50), and unlike them and those of *Citrullus vulgaris* are fairly frost-resistant. Many were still green during the heavy frosts experienced on the expedition, and were even putting out fresh leaves. They often have a zig-zag growth form and may root at the nodes. Apparently they die back after a few seasons, for live and dead runners were common. The leaves, borne on a one-inch or two-inch stalk, are dull green, lobed, very rough to the touch, and between two and four inches long. A stout slightly hooked tendril rises at the base of each leaf and is usually about as long as the leaf-stalk. The fruits vary in shape from ovoid to nearly spherical, and weigh about half a pound. The skin is covered with thick soft spines a quarter to half an inch long, and is pale yellow when the fruits are ripe. They can stand heavy frost without spoiling, and are eaten by many different animals.

The plant has been recorded from the sandy parts of the north-western Cape Province and Orange Free State, the Transvaal, the Bechuanaland Protectorate, South West Africa, Angola and Northern and Southern Rhodesia. On the expedition the runners were common between Molepolole and Ghanzi but the fruits, in tens or in hundreds, were in patches sometimes many miles apart. The plants were not found on the firmer " pan " soils and were much less common north of Ghanzi.

The fruits have a thin rind containing numerous flattened white seeds embedded in a green translucent jelly-like flesh which may be eaten raw or roasted and has a distinctive, slightly rank flavour. The pips and skin are often roasted separately and pounded to make en edible meal. As a source of water this plant comes next in importance to *Citrullus vulgaris*, but like *Citrullus vulgaris* (and *Cucumis hookeri*) it cannot be depended upon where there have not previously been adequate rains, for the water in its perennial tap-root is not in itself enough to produce a crop of fruit.

Citrullus naudinianus has possibilities as a cultivated plant.

Citrullus vulgaris Schrad. (4937, 4999) Photograph 57.

!hõ: Bushman.....	dam
ǁganakwe Bushman...	nǁan
ǀgikwe Bushman.....	nǁan
Naron Bushman.....	nǁa-ī
Eastern !khũ Bushman	-t'a-ma

This plant, one of the melons and commonly known as the tsama, has stout six-foot vines half an inch in diameter at the base and a quarter of an inch at the tip. They are covered rather densely with light brown hairs, which turn white and stiff with age. The vines are usually prostrate, but occasionally festoon themselves over grasses and low shrubs with the help of small Y-shaped tendrils, curly at the tips. The leaves are borne on two-inch stalks and are hairy on the ribs, dull green, rough to the touch and deeply lobed. Each plant produces male and female flowers. They are an inch in diameter and pale yellow, and the fruits which follow are rounded and up to six inches in diameter and six and a half pounds in weight. As many as 34, of all sizes, have been counted on one plant. The rind, densely hairy when young but later quite smooth, is dark green mottled longitudinally with light green, and contains a crisp, juicy, tasteless white flesh in which numerous flattened brown seeds are embedded. The melons can endure heavy frosts without becoming spoilt, but the rest of the plant is very susceptible. The frosts, however, merely hastens its death for it is in any case an annual.

This melon is indigenous to south-west Asia and the warm dry regions throughout Africa. The water-melon is merely an improved variety of the same species, which has been known in Egypt and Babylonia since the beginning of history (Marloth, 1913-1925: III: II: 205). The tsama was widespread but patchy along the route of the expedition, and areas of abundant melon alternated with long stretches where it was not seen. It was not confined to the sand but grew also on the hard soil of the pans.

The tsama is unquestionably the most important plant to the Bushmen in this part of the Kalahari. They are known to use it as their sole source of water for months on end and it is extremely doubtful whether they would be able to live permanently in the Kalahari without it. Its importance is shown by the fact that one group of Bushmen in the central Kalahari had a small patch of tsama which they had grown from seed, and the Bushmen are not as a rule agriculturalists. Nevertheless, the tsama is not an infallible standby, for the reasons given in the discussion on *Citrullus naudinianus,* and when the need arises the Bushmen can and must substitute more meagre but at the same time more reliable sources of water, for example from *Sansevieria scabrifolia.* When it is used for drinking-water the melon is opened at the top like an egg and the central portion cut out and eaten. The rest of the pulp is then mashed inside the rind with a stick to a watery mass which is half drunk and half eaten, the pips being put aside and later roasted and pounded (without being peeled) to make an edible meal. The melons are sometimes roasted before being eaten, which adds a little flavour, and they may be cut up and mixed with meat to form a stew, which is conveniently cooked in the rind itself. Although no bitter specimens of the tsama were found along the route of the expedition, they do occur. Their flesh is poisonous and unfit for human consumption, but their seeds are free of poison and edible after roasting.

At some villages of Bakalahari (which are a Bantu tribe), the tsama is regularly cultivated. These and wild melons are collected and stored under shelter, and goats, horses, cattle and even dogs are kept with tsama as the main source of water. The livestock use the melon more economi-

cally than the Bantu and Bushmen do, for they eat the rind as well. Large animals, and this according to Livingstone (1857: 48) includes the carnivora, are able to broach the tsama rind unaided, but evidently the smaller animals do not find this easy, for many tsamas were seen with the marks of teeth on them, showing where animals had attempted unsuccessfully to reach the pulp inside. As for the rodents, whose burrows were seen by the thousand all through the central Kalahari, they are well equiped for making holes in the rind, and apparently have little difficulty, for hollowed-out tsamas were frequently seen.

Cucumis hookeri Naud. (5012, 5028, 5047) Photograph 58.

!hɔ: Bushman..... n≠ɔ?nu
Naron Bushman..... n≠ɔ?nu

An annual vine with slender straight stems up to six feet long, and a shallow spreading root system. It produces tendrils and may occasionally trail over low shrublets and tufts of grass, but normally it is a runner over the surface of the sand. All parts are covered with minute stiff white hairs, which are densest on the leaves, particularly on the under surface, and make them rough to the touch. They arise singly at intervals of up to four inches, vary from one to three inches in length, and are dark green with large rounded lobes, and stalks up to one and a half inches long. The tendrils arise at the base of the leaves. They are an inch long and are tightly curled at the tip. Both male and female flowers, borne on the same plant, are yellow and trumpet-shaped with triangular petals, and an inch in diameter. The fruits are the size of a hen's egg, brown with six or seven longitudinal lighter stripes and covered with soft but fairly stout prickles, the flesh being green, transparent and almost jelly-like, with the smell of cucumber.

This is a widespread species through the drier and sandier parts of the northern Cape, the Transvaal, Southern Rhodesia, the Bechuanaland Protectorate and South West Africa. It was found all along the route of the expedition in the open grasslands, and sometimes in great abundance. The fruits were undamaged although the leaves and runners had been killed by frost by the time the expedition passed through the Kalahari.

The fruits have a slightly sour taste but are good to eat, and as they have none of the thick white layer of firm flesh which surrounds the pulp of the cultivated cucumber they contain proportionately more moisture and are a useful source of water. Bitter fruits are known to occur in some strains of this species and are to be avoided, not only because of their unpleasant taste but also because they are poisonous.

Cucumis metuliferus E. Mey. (5098) Photograph 59.

An annual climber over trees and shrubs with angled, sometimes almost winged 10-foot vines thickly covered with stiff brown hairs and bearing the leaves at intervals of three inches or so. The leaves, which are covered with similar hairs, have three or four rounded or acute lobes and small teeth along the margins. They are up to three inches long and arise from a two-inch stalk, at the base of which is a tightly-spiralling tendril. The flowers are trumpet-shaped, yellow and, including the small triangular petals, about an inch across. The immature fruits are dark green mottled with lighter green. They ripen during the winter and are then bright orange, five inches long and half as wide, and armed with hard and exceedingly sharp spines which can injure the skin if carelessly handled. They have a thin rind covering a green transparent flesh in which the seeds are embedded.

The plant is widely but scantily distributed through the northern and eastern Transvaal, the Bechuanaland Protectorate, South West Africa and Rhodesia. One specimen was collected near Tsau.

Edible and bitter varieties of this cucumber are known, but there is no way of distinguishing them except by experiment. The specimen from Tsau had inedible fruits, not because of any noticeable bitterness but because of a most disgusting flavour which persisted in the mouth for an hour or so after a small piece had been tasted. Miss I. C. Verdoorn of the Division of Botany informs me also that the spines are soft on the fruits she has examined, and it is possible that No. 5098 is, because of its hard spines and bad taste, a distinct strain.

Cucumis metuliferus is cultivated in various countries under the name of Jelly Melon.

Cucumis sp. (4895, 4986, 5027, 5320) Photograph 60.

!hɔ̃: Bushman.....	n‖am
‖ganakwe Bushman...	umn|i
|gikwe Bushman.....	kwamn|i and ‖gam
Naron Bushman.....	n‖am
Eastern !khū Bushman	huru and uru

A vine with slender prostrate straight stems about six feet long. The whole plant is rough to the touch from a covering of hairs similar to those of *Cucumis hookeri* and distributed in the same way, and it has the same type of tendrils and the same habit. In size, shape and spacing the leaves vary somewhat, but the margins appear to be consistently rather jagged. Male and female flowers are alike in size and shape, and yellow. They are borne on different plants. The fruits are extraordinarily like those of *Cucumis hookeri*, but they have about ten longitudinal gray stripes instead of six or seven, prickles tending to curl over more at the tips, and more of them, the proportion being about 324 to 186. The seeds, too, are bigger. The fruits tested were intensely bitter without exception. The roots of the many female plants investigated were pale brown, about two feet long and less than a quarter of an inch thick, and bore a thickened storage organ at the end which varied according to its age, being the size and shape of a short candle when young and like a large potato when old. The runners radiate out from a central root and in turn send down roots at intervals, and although the intervening parts wither and die during the winter the roots themselves appear perennial, and probably form new plants, for a root sent from the Kalahari grew into a flourishing plant in Pretoria the following season. As the vines had been frosted and had partly disintegrated when these plants were studied in the field, I could not establish whether the male plants had the same root system. This is, however, probable, because the same root system was found on many vines which were not bearing fruit.

This plant has seldom been collected and is apparently undescribed. It is represented in the National Herbarium by only three other specimens apart from those collected on the expedition. It was found in the central Kalahari (where it was sometimes abundant) and also in the north near Gautscha Pan, and, like *Cucumis hookeri*, in open grasslands. It was seen only on deep sand. No estimate of the relative abundance of this species and *Cucumis hookeri* can be made in the winter without careful investigation because of the similarity of the two when once their leaves have gone.

The storage organs are firm but juicy and may be eaten raw or cooked. The flavour is pleasant, rather like that of a turnip, and if they are eaten raw they are a valuable source of water. They were an important article of food to the Bushmen we met in the central Kalahari, and the plant would be worth investigating with a view to cultivation after improvement through breeding.

Coccinia rehmannii Cogn. (4954, 5029) Photograph 61.

!hɔ̃: Bushman.....	m⊙wajé:
ǁganakwe Bushman...	ǀga:
ǀgikwe Bushman.....	ǀga:
Naron Bushman.....	ǀga:
Eastern !khũ Bushman	ǀga:

A vine, climbing by means of tendrils to a height of six or eight feet, and bearing on half-inch petioles a dense growth of dark green leaves which are deeply and irregularly lobed and very variable in size and shape. They have a rough texture from minute scattered white hairs, more numerous on the upper surface and pointing forward. The stems are slender and angled, and bear a few of these hairs also. The plants are either male or female, and both male and female flowers are trumpet-shaped with short triangular petals, pale yellow and three quarters of an inch across. The fruits are three quarters of an inch long, with a bulbous base and a rather thick neck, green mottled with white when immature and red when they ripen in the autumn. The old stems die back during the winter and new ones are produced the following spring from a perennial tuber buried about four inches below the surface of the ground. The tuber tapers gradually when young, but thickens and assumes various shapes as it grows older, and the bark, from being smooth, becomes rough and fissured. It does not "bleed" if injured superficially, but from deep injuries it exudes a clear astringent mucilage.

Specimens on the expedition were found not in the open grasslands, but always growing in shelter under a bush or in a thicket. It was midwinter and they were dormant, represented above ground by a few fragments of dry and leafless stringy stem among the twigs of the sheltering tree, and in consequence exceedingly difficult to find. Even after the presence of the plant had been established the finding of the tuber presented difficulties, for the connection with the vine overhead was often broken. The plant appeared to be occasional but widespread in the parts through which we travelled, and three tubers, all of which were successfully cultivated in Pretoria, were collected in different parts of the Kalahari. It is recorded also from the Cape Province, the Transvaal and South West Africa.

Besides providing food, the tubers are sappy enough to be a useful source of water, but they must be roasted first for they cannot be eaten raw. Older woodier tubers are best boiled, but even so the fibre is so tough that it is ejected after being chewed. At all stages the tubers are rather tasteless. They are known also to the Natives in some parts of the Transvaal, and eaten by them, but in this land of relative plenty they are not a popular food. The fruits also are edible, but rather sickly sweet and flavourless. Doubtless they are used by the Bushmen, but I failed to ask them.

Coccinia sessilifolia (Sond.) Cogn. (5167) Photograph 62.

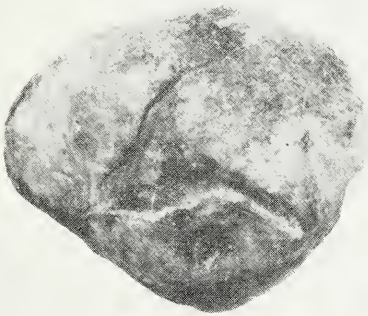
Eastern !khũ Bushman ¯k'i:dwa

A vine with many slender stems and bluish-green sessile leaves, deeply and irregularly lobed but usually less so than those of *Coccinia rehmannii*. The are covered with tiny raised scales on the upper surface, which sometimes show through on the lower surface as dots, and although hairs are present they are nearly all confined to the margins and too small to be seen by the naked eye. The tendrils are produced at the base of the leaves. Male and female flowers are borne on different plants. They are superficially alike, and similar to those of *Coccinia rehmannii*. The fruits are ovoid, three inches long and one in diameter, and are bright red when ripe. The leaves drop during the winter, and the vines also wither and disintegrate, but fresh ones arise in the spring from a perennial tuber weighing up to 25 pounds or so and similar in all respects to the tuber of *Coccinia rehmannii*.

Although the plant has a wide distribution on a variety of soils in the Cape Province, the Orange Free State, the Transvaal, the Bechuanaland Protectorate and South West Africa, it was not seen on the expedition until Nama Pan was reached, where it was growing under the shelter of trees in sand. Two tubers, which happened to be male and female respectively, were sent to Pretoria, and flowers and fruits were produced in the summer of 1955-56.

Both tuber and fruit are edible. The tuber, which is prepared by roasting or boiling, is fibrous and rather tasteless. The fruits may be eaten raw when ripe, and although sweet are without much flavour. They are best used for food when gathered green and cooked as a vegetable. Their texture is then fairly firm and their flavour like that of Asparagus. An added advantage of using them green is that one avoids the larva of a certain fly which, in Pretoria at any rate, often heavily infests the more mature fruit.

It is of interest to note that although there is a record in the National Herbarium that birds eat the fruit and that the tubers are dug out and eaten by buck, there is no record of the fact that the plant is eaten by human beings. On the contrary, the information on one specimen is " Fruit is very poisonous to children " and on another " Toxic ".



1. *Terfezia* sp. [*Photo: King.*

2. *Ophioglossum sarcophyllum.* [*Photo: Reyburn.*

3. *Typha capensis* — Half natural size. [*Photo: Reyburn.*

4. *Mariscus congestus.* [*Photo: Story.*

5. *Scilla* sp. (5190) [*Photo: King.*

6. *Scilla* sp. (5181) [*Photo: King.*

7. *Sansevieria scabrifolia.* [*Photo: Reyburn.*

8. *Walleria* sp. [*Photo: King.*

9. *Eulophia* sp. nearest *E. pillansii*. [*Photo: Reyburn.*

10. *Eulophia* sp. No. 5213. [*Photo: Reyburn.*

11. *Ximenia americana* var. *microphylla*. [*Photo: Reyburn.*

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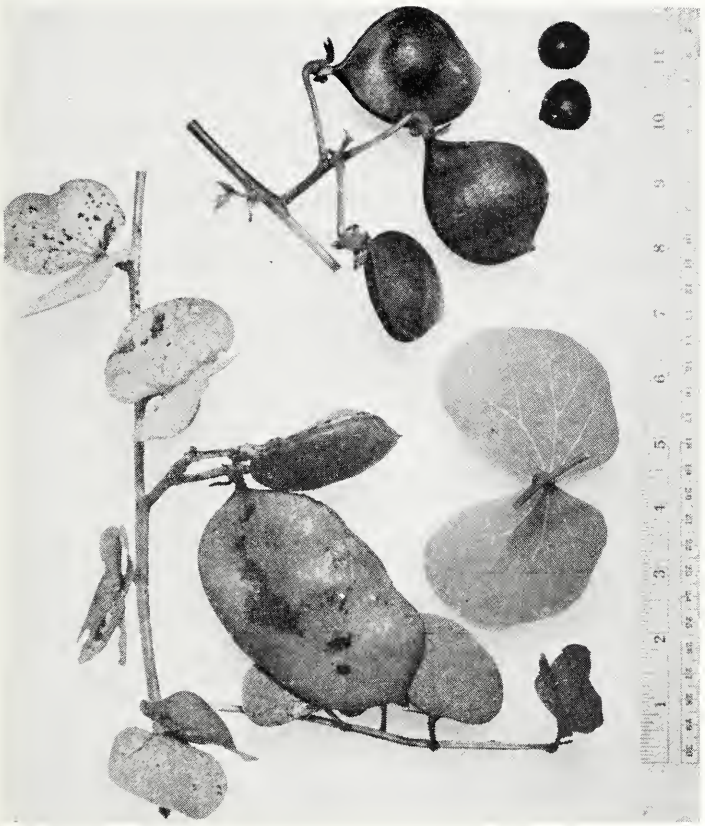

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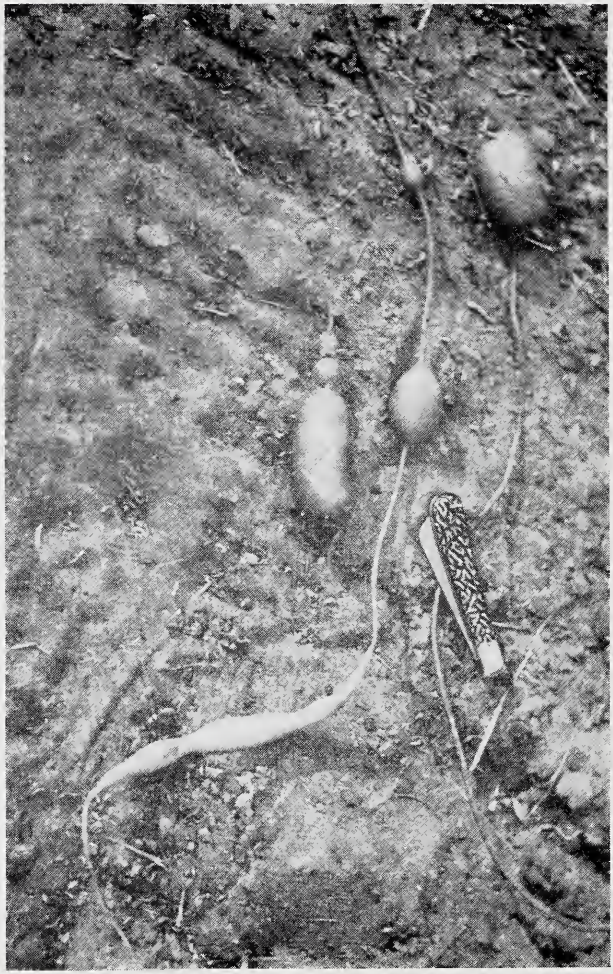

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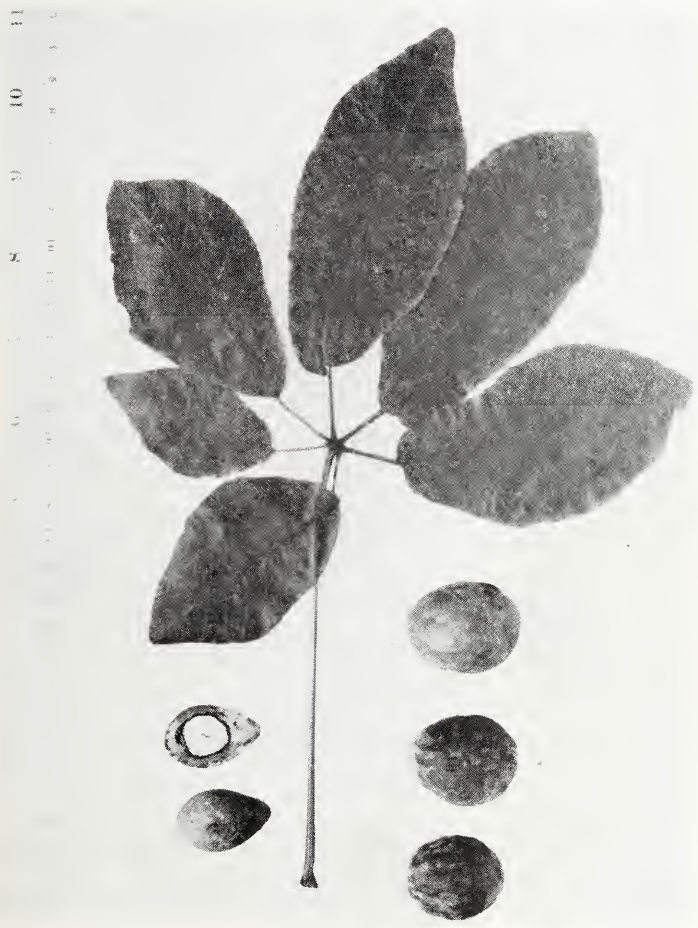

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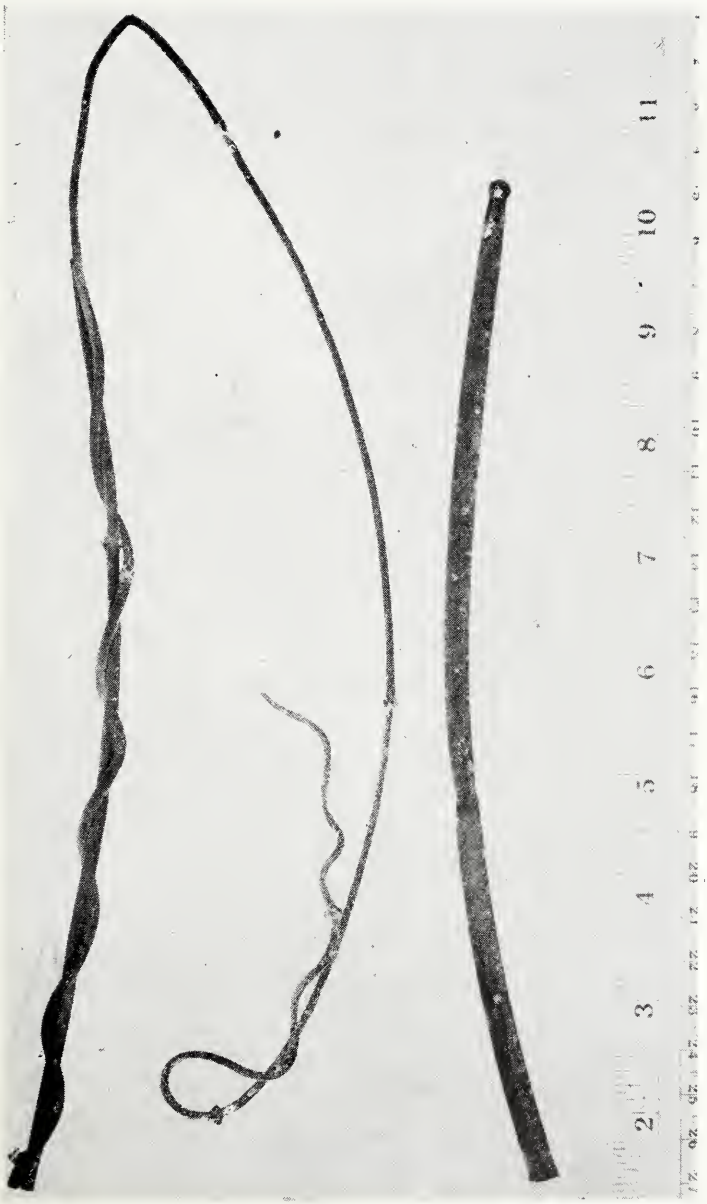

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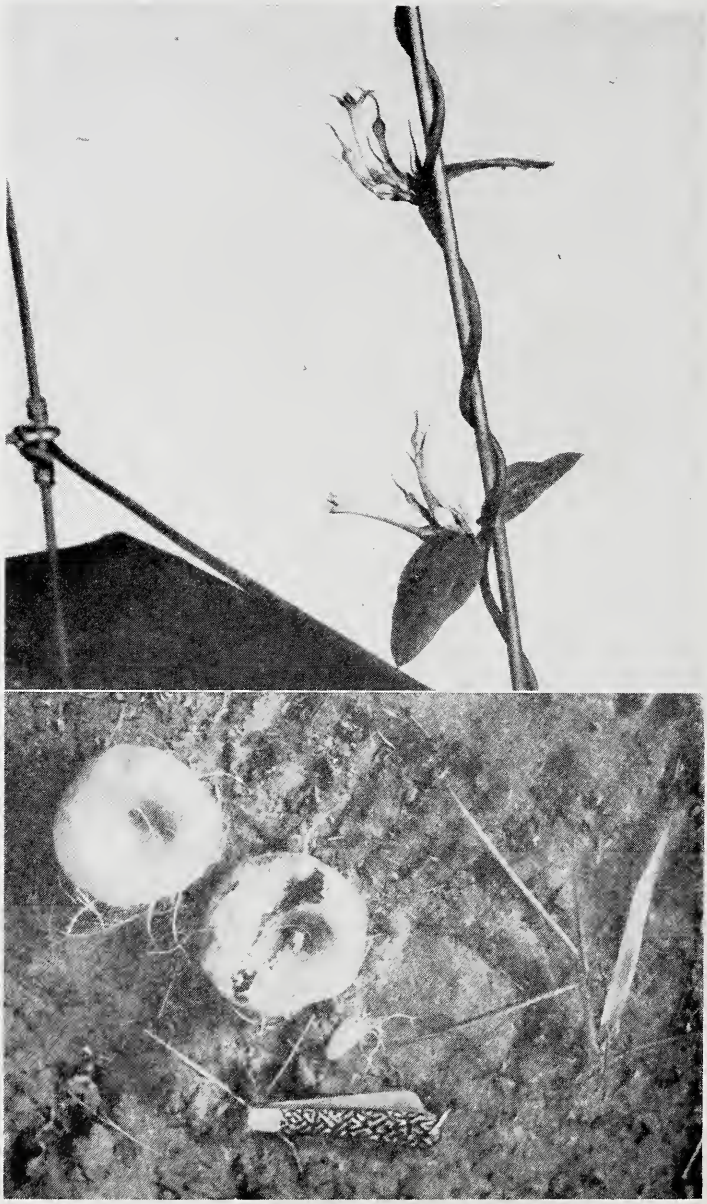

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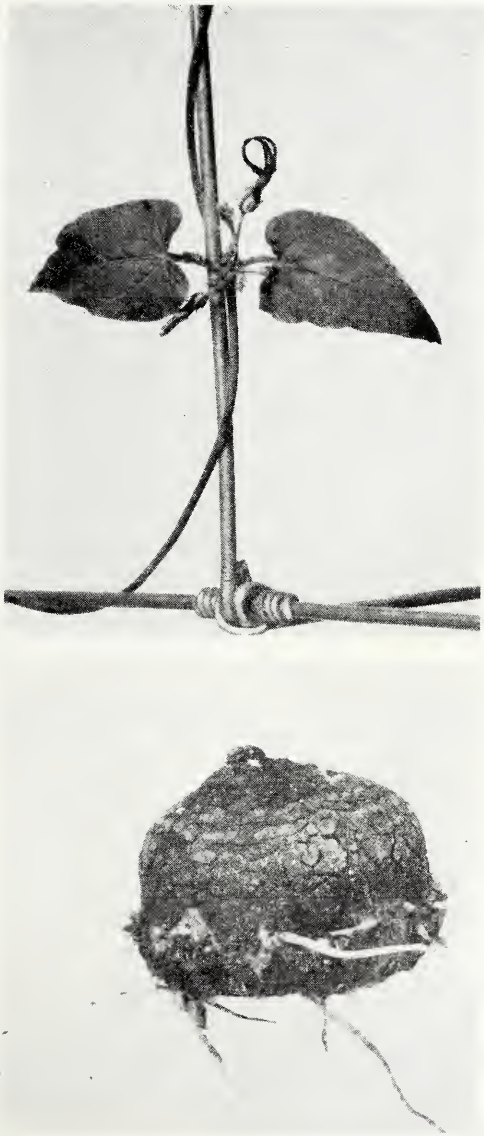

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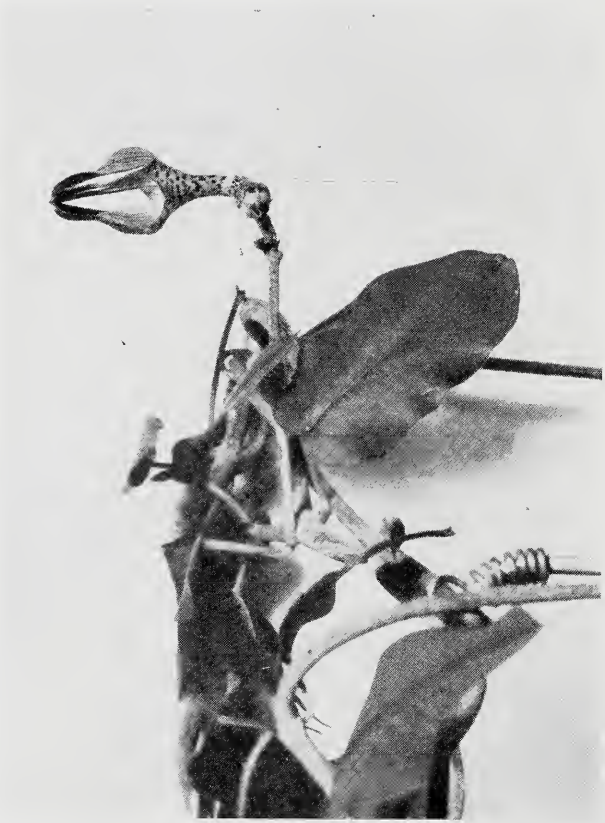

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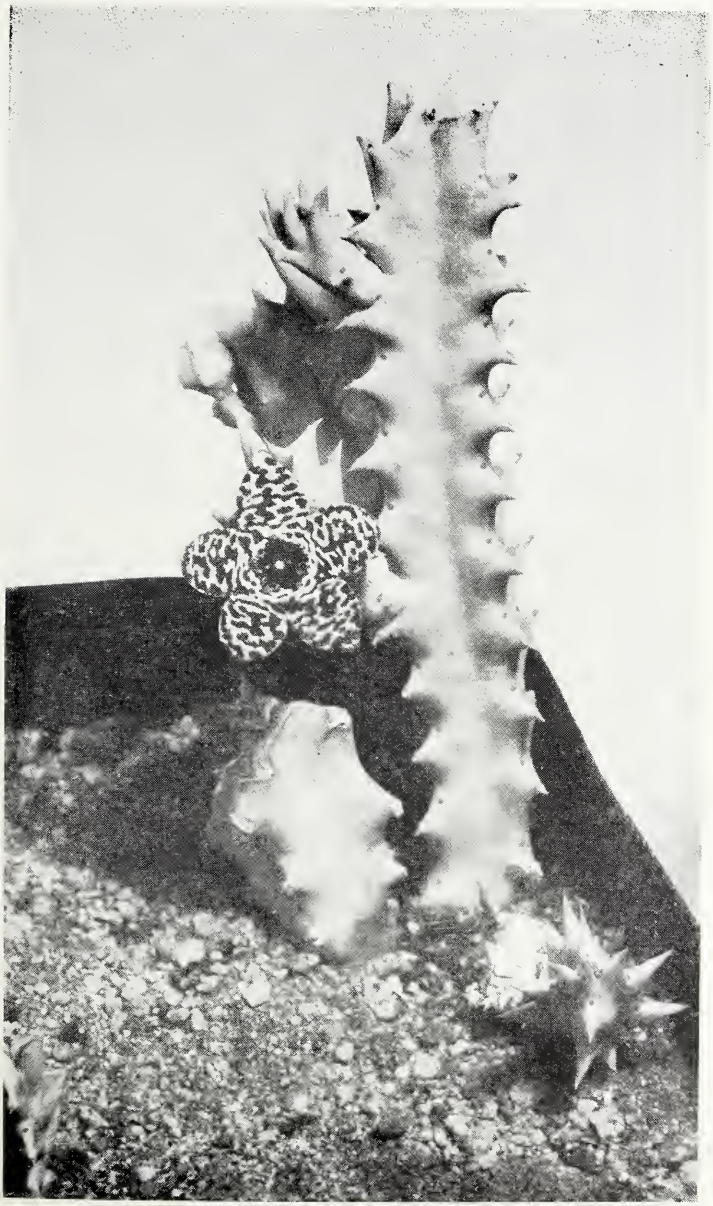

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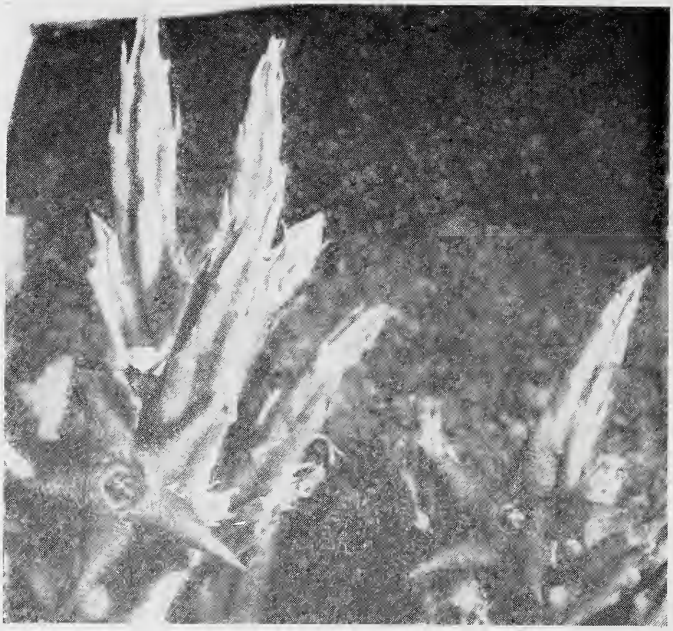

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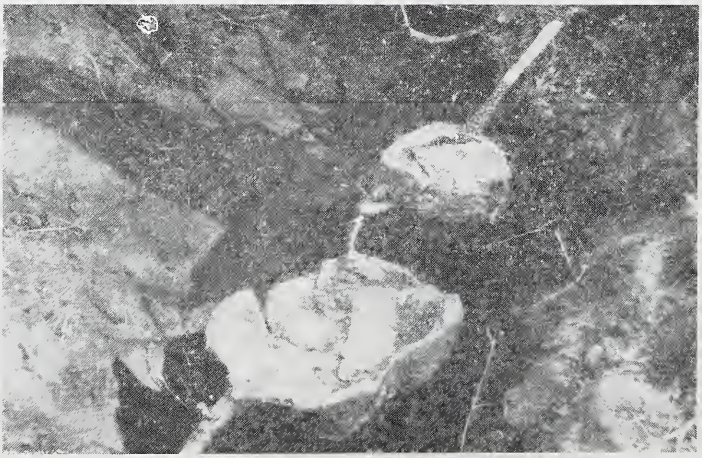

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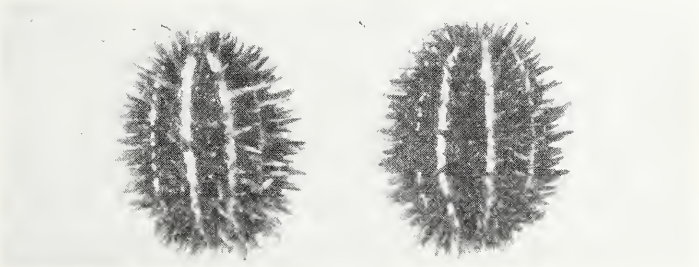

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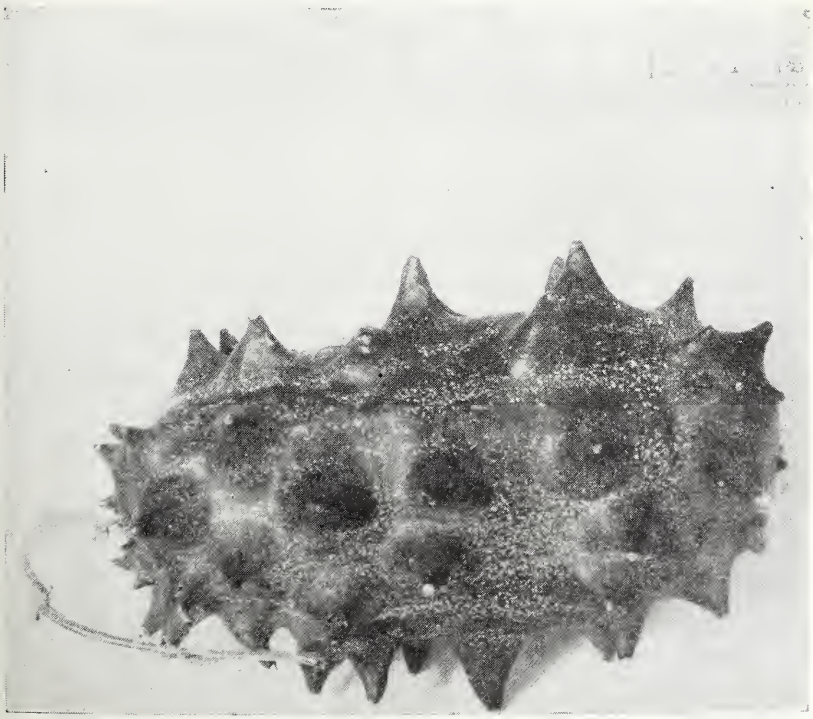

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By

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Thesis Approved by the University of the Orange Free State, Bloemfontein, for the Degree of Doctor of Science in the Faculty of Science

by

J. W. C. MOSTERT, D.Sc.
Senior Pasture Officer, College of Agriculture, Glen, O.F.S.

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FOREWORD.

This study of the vegetation of the Bloemfontein and Brandfort Districts was carried out by J. W. C. Mostert under the guidance of Dr. W. J. Lütjeharms, Professor of Botany of the University of the Orange Free State, and a member of the Botanical Survey Advisory Committee of the Department of Agriculture. The full thesis was accepted for the degree of Doctor of Science, and it has since been edited for publication in the Botanical Survey Memoir series. It will be the means of advancing botanical knowledge of an area with a very meagre literature up till now.

In gathering his information, Dr. Mostert laboured diligently for a number of years over a wide field of study. The thesis is mainly an objective study of the vegetation and its environment and will be of considerable value to students taking a botanical course at the local University. It will at the same time be a source of reference for pasture research and other departmental officers who operate in that area.

The author agrees with other observers in stating that the greatest damage to the vegetation was caused subsequent to the penetration into the area of the European farmer. Deterioration set in due to intensive and continuous grazing by stock. He attempts to show the road leading to the recovery of the vegetation and the means by which it can be stabilised at a safe and profitable level.

It would be well for the farming community to take special note of the statement that past experimental records prove that judicious veld management, especially the aspect of controlled grazing with cattle and sheep together, lead to the restoration of the natural vegetation to its optimum carrying capacity.

R. A. DYER,
Chief Division of Botany and Director of Botanical Survey.

PRETORIA,

October, 1957.

INTRODUCTION.

This study was started in 1949 when the writer was transferred to the Glen College of Agriculture, and comprises principally an ecological investigation of the vegetation in parts of the Bloemfontein and Brandfort districts. Surveys and lists of the plant species collected are included and their agricultural potentialities are considered.

It is felt that apart from its academic value an ecological study such as the present one is of fundamental importance and a pre-requisite for pasture management experiments. This study may serve, therefore, as a basis for the planning and interpretation of veld grazing experiments which are to be initiated on an extensive scale at the Glen College of Agriculture.

In the initial phase of the work plant collections were made and a herbarium was built up in order to obtain a list of the plants of the area around Glen. Notes were made on the habitat and distribution of the species and gradually the work was extended, different communities were described and more detailed surveys made.

Up to now ecological studies of the vegetation of the Union of South Africa are generally lacking in detailed surveys of the various plant communities. It was, however, felt that such surveys would be much more illuminating than mere physiognomical descriptions of the vegetation types and would add to the ecological value of this thesis. An attempt was also made towards a preliminary characterisation of some of the open communities, e.g. Grassveld, Gannaveld, etc., on the basis of the data which the writer has collected. As this study was not initiated as a sociological study the experimental procedures followed in the earlier stages of the work have not always been the ideal and the data obtained are sometimes insufficient for a proper characterisation of the communities. As well as from the academic point of view, the vegetation is considered from the practical agricultural aspect. For this reason various botanical surveys of veld management trials are included.

A map is attached showing the veld types and places where botanical surveys were made at the Glen College of Agriculture. Various veld types, e.g. Themeda grassveld and Kalkveld, Valley-Vlei grassveld and the Valley Acacia Bush community were often found to be so intermixed, or distributed over such small areas, that an exact location on the topographical map could not be made.

Most of the plants collected by the writer were identified at the National Herbarium, Pretoria. The specimens are preserved in the herbarium of the Glen College of Agriculture. The writer also had access to the herbarium of the University of the Orange Free State and the check list of the flora of the area investigated is considerably augmented by the addition of these records.

In the compilation of the check list the taxonomic system of Phillips's *Genera of South African Flowering Plants* (1951) is used.

De Klerk (1951 to 1952) gave a general review of the early agricultural activities and especially of the sheep farming in the Orange Free State during the pioneering stage, i.e. 1821 to 1856. He showed that in 1821, i.e. a few years before the Great Trek, the first European farmers trekked across the Orange River with their stock in search of grazing in the Trans-Orange. As a result of frequent droughts and locust outbreaks the stock farmers again entered the Trans-Orange in 1828 when the foremost of them settled along the Modder River. By 1830 the migration across the Orange River was regular and developing rapidly. About this time farms in the area known today as the Bloemfontein district were purchased by the stock farmers from the Griquas. After 1834, when the Great Trek started, the colonization of the southern and central Orange Free State took place rapidly. De Klerk further stated that fencing of the farms started in 1881 and in this connection it is claimed that Dr. O. C. H. Krause, the first qualified physician in the Orange Free State, was the first person in the Bloemfontein district to fence his farm and also the first to install a self regulating windmill. This he did in 1887. Today all farms in the area studied are fenced and usually divided into camps which are often watered.

Before the advent of the European farmer, the southern and central Orange Free State carried thousands of antelope and it is not impossible that fluctuations in the composition of the veld occurred as a result of intensive grazing, fires, droughts and locust invasions. There is no available evidence, however, to indicate the botanical composition of the veld or its fluctuations prior to European settlement. Nevertheless it is certain that changes in the botanical composition of the veld have taken place during the past century and it is generally assumed that the greatest damage to the veld was caused after the advent of the European farmer by intensive and continuous grazing by cattle and sheep.

The destruction of the natural grassveld, the encroachment of karroo bushes and shrubs at the expense of the grassveld, and the danger of soil erosion in South Africa have been stressed by various writers and by officials of the Department of Agriculture. The veld on numerous farms in the parts studied is covered by the almost valueless *Tribulus terrestris* and *Chrysocoma tenuifolia* and by inferior pioneer grasses like *Aristida* spp., *Chloris virgata* and *Tragus* spp. which may become dominant. The valuable climax grass *Themeda triandra* and associated perennial grasses have been destroyed on many farms and bare patches in the veld are conspicuous. What has already happened to the veld in parts of the southern and central Orange Free State may also take place in the grassveld in the higher rainfall areas of the Orange Free State.

All available evidence and experimental data indicate that judicious veld management, especially with a proportion of cattle in sheep areas, is necessary for the restoration of the natural vegetation and the original carrying capacity of the veld.

It is well known that only a little of the total area of the Union of South Africa, approximately 10 per cent, is arable or suitable for cultivation. The rest is principally suitable for the livestock industry, and as the livestock industry depends almost entirely on the natural veld it is important that a detailed study of the veld occurring in the different climatic regions should be made. Such a study is a complicated task requiring the combined attention of the ecologist, pasture-research worker, soil scientist, animal husbandry officer, etc. A basic study is necessary not only of the plants and plant

communities found in the different edaphic and climatic regions in South Africa but also of the palatability of the species and their response to different grazing and farming practices. Moreover a good knowledge of poisonous and edible, annual and perennial, pioneer and climax species is of fundamental importance for the pasture research worker, as well as for the farmer. For proper utilization and conservation of the veld, the natural vegetational and climatic areas should be determined so that only those farming systems may be adopted which are in accord with the ecological conditions of each area—otherwise an unstable vegetation and soil will result.

As the rainfall of the Bloemfontein–Brandfort area is erratic and too low for the economic production of crops, the most stable and important type of farming is with sheep and cattle. Crop production is usually limited to drought resistant fodder crops.

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DEFINITIONS OF A FEW AFRIKAANS TERMS USED IN THE TEXT.

Bult.....	High lying areas or raised ground.
Gannaveld.....	Veld in which *Salsola* spp. predominate.
Kalkveld.....	Vegetation occurring on lime soils.
Koppie.....	Cone-shaped hill.
Kraal.....	Enclosure for stock.
Pan.....	Depression.
Randjieveld.....	Vegetation occurring on the hills, ridges and koppies.
Sloot.....	Ditch or eroded drainage channel.
Spitskoppies.....	Cone-shaped hills with steep sides.
Spruit.....	Watercourse.
Tulp.....	*Moraea* or *Homeria* spp.
Vlei.....	Marsh or swamp.

CHAPTER 1.

TOPOGRAPHY, GEOLOGY AND SOILS.

The area concerned comprises north-eastern portions of the Bloemfontein and southern-central parts of the Brandfort magisterial districts. It totals approximately 1,000 square miles and represents a portion of the great inland plateau of South Africa. It extends from approximately latitude 28° 42′ to 29° 11′ south and longitude 26° 6′ to 26° 33′ east.

The geology, topography and soils of this area are best treated under separate headings.

1. TOPOGRAPHY.*

The rocks of this area are built up of more or less horizontal-lying Karroo beds, i.e. alternating layers of relatively soft shales and of harder sandstones intruded by still harder dolerite sills, dykes, pipe-structures, etc. The wearing down of this area under the action of different weathering agents gives rise to the typical Karroo landscape. The more diversified landscape (in the form of " spitskoppies " or elongated hills and ridges) is due to the differential weathering of hard and soft material. The large flat or slightly undulating areas are chiefly formed by shaly material. The " spitskoppies " consist principally of dolerite. Dolerite dykes also give rise to long ridges which may sometimes be traced for miles over the gently undulating surface. The dolerite sills give rise to elongated hills usually with the sill forming the top hard part of the hill. The slopes may be steep and concave if the underlying material consists of shale; where the underlying material is alternating sandstones and shale a number of structural terraces is found usually formed by the sandstone.

As has been indicated on map No. 3, the hills, ridges and koppies occur mainly north of Bloemfontein towards Glen, Karree and Mazelspoort. The largest hill in this area is the Keeromsberg near Brandfort which is a little more than 400 ft. higher than the surrounding plains. Generally the altitude of the area varies between 4,200 ft. on the western plains near the Modder River and 5,100 ft. at the top of the Keeromsberg. The surface of the area studied is fairly flat to gently undulating. Generally a slight slope occurs towards the Modder River.

The whole area is drained by the Modder River with its numerous tributaries of which the Osspruit, Rhenostersprui and Doornspruit are the largest and most important. Fountains are absent and the Modder River and its tributaries are entirely dependent on the rain for their flow, which is very irregular and erratic. After heavy rains a strong flow occurs but it lasts for only a few days, and for the greater part of the year the local spruits and vleis are dry watercourses. As the Modder River drains a larger area than its tributaries its flow after heavy rains usually lasts a few days longer than that of the spruits. The uniform topography is to a great extent reflected in a rather uniform vegetation.

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* Information under the headings Topography and Geology is drawn mainly from A. L. du Toit's *Geology of South Africa* (1926) and L. C. King's *South African Scenery* (1942). No detailed geological map of the Bloemfontein–Brandfort area exists.

2. GEOLOGY.

The area investigated consists of rocks of the Karroo system. Approximately 80 per cent of the area is covered by rocks of the Beaufort series. In the remaining north-western part of the area the Ecca series is found. The Beaufort series follows the Ecca series conformably. The two series are clearly distinguished by geologists. The intrusive dolerite is ubiquitous, the strata being intersected by legions of sills and dykes.

1. The Ecca Series.

The Ecca series is a group of shales and sandstones. Of importance in this area are the upper Ecca beds " consisting of soft blue shales becoming flaggy towards their summit " (Du Toit 1926). The topography is undulating or flattish and may be dotted with ridges and small hills due to intrusive dolerites. In this area bluish and greenish shales are exposed in the bed of the Modder River where it flows in upper Ecca approximately five miles west of Glen.

2. The Beaufort Series.

The Beaufort series is subdivided into three, the lower, middle and upper series. The middle and upper Beaufort layers are not present in the area studied. The lower Beaufort series forms a contrast to the dominantly shaly underlying Ecca beds in having bands of fine to medium grained yellowish and felspathic sandstone, " alternating with thick bodies of blue, green, or occasionally red to purple mudstone and shales, sometimes with calcareous nodules " (Du Toit 1926). In the Bloemfontein–Brandfort area purplish mudstone and shales are the most characteristic. If this shale and mudstone are exposed to weathering for a short time they are reduced to a mass of irregular fragments.

3. Secondary Limestones.

Secondary limestone has largely been derived from the decomposition of lime-bearing basic igneous rock in its neighbourhood. Such surface limestones have a wide distribution in South Africa and are more or less confined to areas having an annual rainfall of less than 25 in., that is to say over all but the eastern third of South Africa. Over considerable areas underlain by Ecca shales and basic igneous rocks such as dolerite, more particularly on flattish ground, limestone may occur either as nodules in the soil or as a more or less continuous sheet on top of the dolerite. The limestone is often covered by a superficial sand deposit of aeolian origin. The material which is commonly known as surface limestone or calcareous tufa varies in depth from a few feet to 10 ft. and more and is well represented in the central and western parts of the area under investigation. At certain places, e.g. at Glen, a continuous thin surface layer of sandy-loam soil occurs on a limestone sub-stratum, and small areas of exposed limestone are found from which the surface sandy horizon has been removed. On these limestone outcrops the Kalkveld vegetation (see Chapter 8) is encountered.

4. Weathering of the Rocks.

The most conspicuous form in which dolerite in this area weathers is by exfoliation. This is typical on the dry northern koppie slopes. Principally as a result of mechanical weathering the northern hill and koppie slopes are usually a mass of weathered rounded doleritic boulders and stones with shallow soils. The southern slopes of the large and steep koppies and hills are usually characterised by the presence of a deeper soil (which is mainly due to the cooler and more humid conditions which are characteristic of these slopes), and of large doleritic boulders (for details see Chapter 7).

On chemical weathering of dolerite a red-coloured clayey-loam soil fairly rich in lime but poor in phosphates is formed. Due mainly to chemical weathering a high calcium content and calcium nodules are often encountered on the top and higher slopes of dolerite koppies.

According to Du Toit (1926) the Ecca series furnishes greyish and brownish soils which are often more loamy than sandy and are better for cultivation. Shales of both the Ecca and Beaufort series on weathering give rise to clay minerals. When rocks of the Beaufort series weather sandy soils are derived from sandstone. In the bed of the Modder River the author has observed that the shales of the Beaufort series disintegrate rather rapidly when disturbed. This characteristic undoubtedly accelerates the rate of weathering.

3. SOILS.*

The soils of the Central Orange Free State have not been studied in detail previously and no published data are available. According to Van der Merwe's soil map of South Africa (1941) only two soil groups are represented in the investigated parts of the Bloemfontein–Brandfort districts. Approximately 70 per cent of the surface of the area studied, i.e. the southern, western and central parts, is covered by aeolian sandy soils. This soil group, in which the superficial deposit is built up principally of Kalahari sand, extends from the north-western Orange Free State in a narrow projection past Glen and Bloemfontein. The rest of the area investigated, especially the eastern portion, is covered by heavy alluvial soils. These soils also extend more or less along the Modder River valley in a narrow westward projection.

The aeolian soil belt is commonly called the Hoopstad " Sandveld ". It is characterised by the loose nature of the surface soil. The normal well developed soils of this belt occur in extensive areas and their continuity is broken only by rivers, spruits, pans, koppies and where wind erosion has removed the superficial sand.

The aeolian soils occur on Ecca beds in the north-western part of the area studied and on Beaufort beds in the rest of the area. These soils are independent of their underlying rock and the writer did not notice any difference in the surface soils. According to van der Merwe (1941) " the

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* The information under this heading was drawn mainly from C. R. van der Merwe's *Soil Groups and Sub-Groups of South Africa* (1941).

normal soils on the slopes and on the bults developed from the sand always possess the same morphological characteristics whether the surface layer is 2 or 6 ft. thick, except for a change in colour and thickness of various horizons. The deep well-drained soils consist of a light greyish brown friable to fairly loose sand". The depth of the sand cover varies markedly. Van der Merwe states that it is generally about six feet thick and the writer has observed soil profiles at Glen where the sand cover varies in thickness between 1 and 6 ft. Underlying the sandy soil a compact soil material approximately two feet thick is encountered. The lower section of this horizon consists of hard uncemented ferruginous concretions, about six inches thick.

It has been observed by the writer that the aeolian soils occurring in the central to western portions of the area studied have a rather sandy-loam texture which is in contrast to the typical Hoopstad " Sandveld " described by van der Merwe. The sandy soil in the neighbourhood of Glen can for instance be more correctly classified as a sandy-loam of a slightly denser texture than the typical sandveld.

As the soils are situated on a slight to a fair slope they ordinarily have a relatively quick surface drainage. The internal drainage is also fairly good until the impervious substratum is struck at a depth varying most commonly from 6 to 8 ft.

Generally the pH of the upper layer of the aeolian soils varies between 6 to 7·5.

The sandy soil is liable to wind erosion which is usually most evident during the dry windy spring months. Special precautionary measures, e.g. improving soil fertility by crop rotation and organic matter, strip cropping, establishment of windbreaks, reseeding of old lands and trampled out veld, etc., are essential to prevent the wind-erosion.

The aeolian soils are quite densely covered by grasses. Themeda grassveld is the most characteristic but on overstocked farms Themeda is ousted and replaced by a predominantly *Eragrostis-Aristida* community (see Chapter 8).

All along the valleys and banks of watercourses heavy alluvial soils occur. Recent alluvium occurs locally in a narrow strip on the banks of the Modder River. This alluvial soil consists of a grey sandy material and varies in depth from a few to 20 feet or more. It is not differentiated into horizons and is usually covered by weeds. Adjacent to the alluvial soil and away from the banks of the river towards the foot of the higher-lying bults and koppies, almost level ground is found. The soils are blackish-brown clays, compact when moist and cloddy to granular when dry. The surface horizon varies in depth from 18 to 24 in. and shows very little variation in structure, texture and colour. This level ground varies in width from a few hundred feet to two miles or more. As its inclination is almost imperceptible these soils have poor surface drainage. The internal drainage is also poor and on certain localities vlei conditions are encountered. Where gully erosion occurs fairly thick surface limestone can be seen in the substratum. These soils contain a high amount of soluble salts and are of alluvial origin. The pH usually varies between 7 and 8.

The vegetation consists mainly of the Valley Acacia Bush community and Vlei Grassveld (see Chapters 6 and 8). On drier alkaline spots brack-resistant and drought-resistant species occur typically, e.g. species of the families *Chenopodiaceae*, *Aizoaceae* and *Compositae*. The bults and plains are covered by grassveld (see Chapter 8).

SOIL EROSION.

Sheet and gully erosion are often very bad along the watercourses. The Modder River has very steep banks and its bed has been eroded down to Beaufort shales. The flow of water from the adjacent higher outlying areas readily causes erosion. Erosion is also largely enhanced by the unstable structure of the soil occurring all along the main watercourses. Wind erosion plays a secondary role in the removal of loose surface material from the bare ground. Consequently it is well realised that grazing along the banks of the watercourses should be practised with the greatest care for an increased run-off, due to the disturbance and destruction of the natural vegetation, is rapidly leading to severe erosion. Clear instances of sheet and gully erosion can be seen on the banks of the Modder River between Mockesdam and Mazelspoort. It has been proved that the erosion along the Modder River can be largely controlled by the rounding-off of the steep banks and by assisting nature in the revegetation of these spots by the application of raw organic material, grass and seeds to the bare exposed soil surfaces (du Plessis 1953).

In bigger dongas and " sloots " the run-off has been effectively checked by the construction of ground embankments.

CHAPTER 2.

CLIMATE.

1. TEMPERATURE.

With regard to the influence of temperature on vegetation it has been indicated by a few workers, e.g. Dyer (1937), Roberts (1952), that mean temperature values have little influence on plants and that plants are affected more by temperature extremes which together with the daily temperature fluctuations are of prime importance, and often the limiting factors for plant growth.

The area under investigation is relatively flat, the greatest variation in altitude being approximately 400 feet. Although the highest hills and koppies are only a few hundred feet above the surrounding plains and valleys, a striking difference is often seen between the vegetation on the north-facing and south-facing slopes. These climatic and vegetational differences are discussed in Chapter 7. Great differences may occur in the temperatures of the different slopes of the hills, but they cannot be expected on the relatively flat parts of the area. Because of the drainage of cold air the lowest winter temperatures are usually experienced in the vleis and along watercourses, which are therefore especially subject to frosts.

Since 1936 air temperature records have been kept at the Main Airport, Bloemfontein, near the University of the Orange Free State. Temperature records are also kept at the College of Agriculture, Glen. In Table 1 a record of the air temperature, taken under standard conditions in a Stevenson Screen, is given for the airport for the years 1942 to 1949. In this table the absolute maximum and absolute minimum are bold printed and temperatures lower than freezing point (32° F.) are marked with an asterisk(*).

The data of this table show that the highest temperature recorded during the eight years, at Bloemfontein was 99·7° F. (37·6° C.), and the lowest temperature was 20·0° F. (— 6·7° C.). This indicates an air temperature range of nearly 80° F. (44·4° C.). The yearly maximum occurs in December, January or February and most frequently in December. The minimum occur in May, June or July and most frequently in July. Between 1936 and 1949 the lowest minimum recorded at the Airport, Bloemfontein was 16·2° F. (— 8·78° C.), and at Glen College of Agriculture 14·5° F. (— 9·7° C.) with a grass minimum of 10·4° F. (— 12·0 C.). The lowest minimum grass temperature recorded at Glen between 1921 and 1954 was 6·8° F. (— 14° C.), on 28th July, 1954. The highest maximum temperature recorded at Glen between 1940 and 1952 was 101·5° F. (38·6° C.). At this station there was a temperature range of 91° F. (50·5° C.). The lower minimum temperature at Glen, in comparison to Bloemfontein may be ascribed to the fact that Glen is near the Modder River and approximately 370 feet lower in altitude than the Bloemfontein Airport.

Generally the grass minimum during the winter is approximately 4° F. (2·2° C.) lower than that of the Stevenson Screen so that the vegetation has to endure even lower temperatures than those represented in Table 1.

TABLE 1.—*Air Temperatures; Airport, Bloemfontein.*

Absolute Maximum (AM.), Absolute Minimum (Am.), Mean Temperature $M = \frac{AM. \text{ and } Am.}{2}$, Number of days when Maximum >86° F. and number of days when Minimum <32° F. All in degrees Fahrenheit.

Year.		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly.
1949.....	AM.....	**99·7**	94·5	87·0	83·4	74·2	71·8	68·6	76·5	89·0	92·1	90·4	92·0	99·7
	Am.....	54·7	51·9	49·8	34·3	28·2*	29·9*	**27·4***	28·9*	37·4	38·9	44·1	47·2	27·4
	M.....	76·9	71·9	66·9	62·7	52·9	51·8	48·3	51·7	62·1	66·3	66·5	71·1	62·4
	Days Max. > 86°	25	16	1	0	0	0	0	0	2	10	6	13	73
	Days Min. < 32°	0	0	0	0	3	1	6	5	0	0	0	0	15
1948.....	AM.....	94·2	90·4	83·0	80·8	74·0	71·5	71·6	78·3	86·7	91·3	89·2	**96·3**	96·3
	Am.....	52·3	44·6	45·9	38·5	33·1	25·7*	**23·4***	25·7*	27·0*	40·0	45·4	38·3	23·4
	M.....	71·9	68·5	65·5	59·2	54·8	48·4	49·8	54·7	56·7	64·9	67·9	72·4	61·2
	Days Max. > 86°	15	6	0	0	0	0	0	0	1	6	7	21	56
	Days Min. < 32°	0	0	0	0	0	14	9	0	4	0	0	0	27
1947.....	AM.....	94·5	**95·5**	90·5	85·0	74·5	68·2	68·7	79·8	87·0	90·5	94·0	90·1	95·5
	Am.....	50·5	56·7	43·4	37·3	33·0	27·5*	**20·0***	26·9*	32·5	34·0	44·4	44·4	20·0
	M.....	74·3	75·5	70·6	62·5	53·4	48·5	44·1	56·1	57·9	65·1	69·9	68·8	62·2
	Days Max. > 86°	23	23	11	0	0	0	0	0	0	5	13	5	80
	Days Min. < 32°	0	0	0	0	0	8	19	4	0	0	0	0	31
1946.....	AM.....	90·7	90·3	93·0	80·3	75·5	68·1	70·8	77·9	87·3	91·0	92·5	**97·6**	97·6
	Am.....	53·6	54·8	43·0	38·8	32·1	24·4*	**20·4***	24·6*	32·0*	37·0	45·1	44·8	20·4
	M.....	71·4	71·5	66·5	60·3	55·7	47·1	48·7	51·4	60·7	62·5	69·1	73·9	61·6
	Days Max. > 86°	11	14	8	0	0	0	0	0	2	4	14	22	75
	Days Min. < 32°	0	0	0	0	0	13	8	9	0	0	0	0	30
1945.....	AM.....	95·7	94·4	88·0	82·0	77·7	66·6	69·5	78·6	90·0	92·7	92·9	**96·9**	96·9
	Am.....	54·5	55·3	40·1	28·4*	23·9*	**22·2***	23·1*	22·8*	36·0	32·3	46·4	44·1	22·2
	M.....	72·9	73·1	65·3	61·5	50·7	44·7	46·7	52·5	64·1	63·9	70·5	72·3	61·5
	Days Max. > 86°	17	16	1	0	0	0	0	0	5	5	16	18	78
	Days Min. < 32°	0	0	0	1	8	23	14	7	0	0	0	0	53

TABLE 1.—*Air Temperatures: Airport, Bloemfontein* (contd.).

Absolute Maximum (AM.), Absolute Minimum (Am.), Mean Temperature M = $\frac{\text{AM. and Am.}}{2}$, Number of days when Maximum >86° F. and number of days when Minimum <32° F. All in degrees Fahrenheit (*contd.*).

Year.		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly.
1944.....	AM.....	93·3	89·3	87·1	83·7	77·8	69·1	69·8	79·5	81·9	90·6	89·1	**95·3**	95·3
	Am.....	53·6	45·4	43·5	35·3	**21·8***	26·0*	25·5*	23·6*	26·5*	44·0	43·9	42·1	21·8
	M.....	72·3	68·8	66·8	61·1	50·1	46·4	47·7	55·5	57·5	67·3	68·5	71·9	61·1
	Days Max. > 86°	15	4	2	0	0	0	0	0	0	4	8	18	51
	Days Min. < 32°	0	0	0	0	6	13	15	4	2	0	0	0	40
1943.....	AM.....	90·5	**91·6**	84·9	80·2	70·6	66·1	70·0	68·7	79·0	87·5	84·8	90·4	91·6
	Am.....	44·5	39·9	47·6	38·0	33·8	21·6*	**21·2***	24·0*	30·5*	34·4	37·7	36·6	21·2
	M.....	69·5	67·8	66·4	58·7	51·5	45·7	45·7	46·7	56·4	62·3	65·3	67·0	58·6
	Days Max. > 86°	5	6	0	0	0	0	0	0	0	2	0	6	19
	Days Min. < 32°	0	0	0	0	0	14	13	12	1	0	0	0	40
1942.....	AM.....	**97·7**	93·8	82·7	81·9	75·2	71·5	68·8	76·1	83·8	82·4	94·0	87·0	97·7
	Am.....	51·3	56·8	49·9	31·0*	27·6*	**20·3***	21·4*	30·0*	30·8*	40·8	39·9	48·5	20·3
	M.....	75·1	73·3	66·4	59·5	52·3	47·1	47·9	54·1	58·9	60·3	67·7	67·9	60·9
	Days Max. > 86°	23	13	0	0	0	0	0	0	0	0	10	2	48
	Days Min. < 32°	0	0	0	1	5	12	8	3	1	0	0	0	30
8 Years— Max.....	AM.....	**99·7**	95·5	93·0	85·0	77·8	71·8	71·6	79·8	90·0	92·7	94·0	97·6	99·7
Min.....	Am.....	44·5	39·9	40·1	28·4*	21·8*	20·3*	**20·0***	22·8*	26·5*	32·3	37·7	36·6	20·0
Averages for 8 years	M.....	73·0	71·3	66·8	60·7	52·6	47·5	47·4	52·8	59·3	64·08	68·2	70·6	61·19
	Days Max. > 86°	16·75	12·25	2·9	0	0	0	0	0	1·25	4·5	9·25	13·13	60
	Days Min. < 32°	0	0	0	0·25	2·75	12·25	11·5	5·5	1	0	0	0	33·25

Compiled from data taken from the Reports of the Weather Bureau, Pretoria.

Temperatures below freezing point occurred during the six months April to September but temperatures near freezing point may also be encountered in October. These late frosts often cause damage to crops. During winter the local plants have to endure prolonged chilling, eg. during June, 1945 (see Table 1) the minimum temperature dropped below freezing point on 23 out of 30 days.

The daily temperature fluctuations are of great biological importance. This is especially true for the winter when the sunny days are relatively hot and the nights very cold. In the area studied daily temperature fluctuations of 40 to 50° F. (22 to 27° C.) are encountered in winter and summer. The local plants are therefore subjected, more or less right through the year, to quite large temperature fluctuations.

In Table 1 it is shown that the average maximum temperature of 86° F. was exceeded on an average of 60 days in eight years. January is the hottest month of the year with a mean air temperature of 73° F. (22·8° C.) and 16 days in which the temperature exceeded 86° F. (30° C.). The mean air temperature for February is a little higher than that for December and, for approximately the same number of days, i.e. 12 to 13, the temperature exceeded 86° F. (30° C.). The mean temperature for March is a little higher than that for October.

For an average of 33 days during the year the minimum temperatures are lower than 32° F. (0° C.) June and July are the coldest months with respectively 12 and 11 days in which the temperature falls below freezing point. September was the only month in which the maximum temperature exceeded 86° F. (30° C.) and the minimum was lower than freezing point. Taken over a period of 12 years the maximum temperature, in the area studied, ranges between 101·5° F. (38·6° C.) in summer and 71·6° F. (22° C.) in winter. The minimum temperature has more or less the same range of variation, i.e. 44·5° F. (6·95° C.) in summer to 14·5° F. (−9·7° C.) in winter. The maximum rises rapidly in September and remains quite stable up to November whereafter a still higher rise occurs. From data taken over the eight years, shown in Table 1, it is interesting to note that a lower minimum was recorded in December and February than in November and March, respectively.

During the winter all plant activities are much reduced so that little growth or flowering occurs. Generally it can be said that temperature is the factor limiting plant growth during winter when the summer-growing plants are dormant and their above ground parts killed by frosts. Several trees and karroid shrubs stay green in winter but generally their activities are also very low. Only a few cold-resistant plants, e.g. *Melolobium calycinum*, *Rhus lancea*, *Nestlera conferta*, are found flowering regularly in June or July. There are several winter growing weeds and ruderals which usually start flowering in early spring. Whether this is due to increased length of day or temperature remains an open question. Many other plant activities start when the temperature rises in spring, especially if the rising of temperature coincides with rain.

2. RAINFALL.

The area studied falls within the summer rainfall region. Practically all the rain falls between September and April and 75 to 80 per cent falls during the six summer months October to March.

Thunderstorms are quite common, occurring mostly during the spring and early summer. They are usually short, and the precipitation varies from a few points to about four inches, occasionally accompanied by hail. A total of 18 hailstorms was recorded at the Airport, Bloemfontein, during the months and years shown in Table 2.

TABLE 2.—*Hailstorms Recorded at Airport, Bloemfontein.*

Months.	1942.	1943.	1944.	1945.	1946.	1947.	1948.	1949.	Monthly Totals.
January	—	1	—	—	—	—	—	—	1
February	—	1	—	—	—	—	2	—	3
March	—	—	—	—	—	—	—	—	—
April	—	—	—	—	—	—	—	—	—
May	—	1	—	—	—	—	1	2	4
June	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—
August	—	1	—	—	—	—	—	—	1
September	—	—	1	—	—	—	—	—	1
October	2	2	—	—	—	—	—	—	4
November	—	—	—	—	—	2	—	2	4
December	—	—	—	—	—	—	—	—	—
TOTAL	2	6	1	—	—	2	3	4	18

As can be seen from Table 2 no hailstorms were recorded during December, March, April, June and July. Six were recorded in 1943 and none during 1945 and 1946. They occurred most frequently during October, November, February and May, and seem to occur over small areas or in strips. They often cause severe damage.

Light snow has fallen, but only rarely. During the eight years, 1942 to 1949, three snow storms were recorded at the Airport, Bloemfontein. Two of them occurred in May, in 1944 and 1945, respectively, and the third in August, 1949.

Rainfall records are kept by nine stations in this area, of which five are situated in Bloemfontein. The records of some go back for only 15 years or less. Three stations with records for 24 years or longer were selected. Of these, Bloemfontein (Kings Park) is in the southern portion of this area, Glen in the centre and Brandfort on the northern boundary. They are on a more or less straight line running north and south and at intervals of approximately 18 miles. The differences in their altitude are slight but a marked variation in their rainfall is found.

Table 3 gives the monthly and yearly rainfall totals, the number of days on which rain fell and the monthly and yearly averages for the 24-year period 1928 to 1951 for all three stations. The bold figures in Table 3 indicate the highest monthly rainfall for the year. Although the average annual rainfall may appear to be adequate for a good grass growth, and even for crop production, its effectiveness is greatly reduced by its distribution and unreliability. The differences between the average and extreme precipitations are high (see Table 3). The duration and severity of the dry season as well as periodic summer droughts are of great importance in determining plant growth.

TABLE 3.—*Monthly and Yearly Rainfall Totals and Number of Days on which Rain fell.*

Year.	Station.	Jan.		Feb.		March.		April.		May.		June.		July.		Aug.		Sept.		Oct.		Nov.		Dec.		Total.	
		In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.
1951	Bloemfontein	3·48	8	1·91	8	3·00	9	3·55	7	0·44	4	0·34	2	0·00	0	0·18	1	0·86	4	3·90	9	0·44	4	0·97	5	19·07	61
	Glen	2·72	10	1·19	11	2·72	13	2·14	9	0·23	7	0·27	3	0·06	3	0·21	1	0·45	2	3·01	9	0·59	6	0·41	5	14·00	79
	Brandfort	3·99	8	3·61	11	2·30	7	2·72	9	0·35	4	0·15	4	0·52	3	0·06	2	0·44	4	1·76	6	0·85	6	1·08	4	17·83	68
1950	Bloemfontein	1·42	5	1·21	10	4·65	13	5·18	12	1·70	9	0·26	2	0·62	4	3·33	10	0·60	6	1·67	3	1·86	7	5·35	10	27·85	91
	Glen	1·78	6	2·12	14	3·11	15	3·50	13	1·69	10	0·25	3	0·75	3	2·97	11	0·35	4	0·61	3	1·62	6	6·04	8	24·79	96
	Brandfort	2·06	6	2·95	11	3·98	9	3·52	12	2·81	12	0·12	4	0·41	5	2·61	11	0·04	3	0·31	2	1·66	7	5·64	12	26·11	94
1949	Bloemfontein	0·74	5	4·30	7	1·77	6	0·71	3	0·78	4	0·54	2	0·60	1	0·37	2	0·82	1	0·96	5	3·23	7	4·89	9	19·71	52
	Glen	1·01	7	1·49	9	2·14	9	0·96	4	0·56	5	0·11	2	0·31	3	0·33	3	0·25	2	1·48	8	2·19	6	4·01	7	14·84	65
	Brandfort	2·75	8	3·37	8	2·60	8	0·77	2	0·50	3	0·22	2	0·30	3	0·71	3	0·15	1	1·90	6	1·91	5	2·66	7	17·84	56
1948	Bloemfontein	6·50	6	1·92	8	7·90	12	2·16	4	1·62	3	0·00	0	0·00	0	0·00	0	0·00	0	0·69	3	0·19	1	0·15	1	21·13	38
	Glen	4·02	7	2·04	10	9·19	15	1·85	7	0·67	3	0·00	0	0·00	0	0·00	0	0·00	0	1·48	6	0·62	6	0·11	2	19·98	56
	Brandfort	3·89	12	2·51	7	9·45	14	2·85	5	0·20	1	0·00	0	0·00	0	0·02	1	0·00	0	1·62	4	1·37	5	0·12	2	22·03	51
1947	Bloemfontein	1·95	3	1·61	3	0·54	2	3·28	8	0·95	4	0·20	1	0·00	0	0·00	0	1·82	4	3·03	5	2·10	2	4·20	9	19·68	41
	Glen	2·58	4	1·26	8	0·79	4	4·00	12	0·68	6	0·15	2	0·07	2	0·00	0	1·58	3	1·54	6	0·93	6	5·55	8	19·13	61
	Brandfort	1·25	7	2·69	6	0·64	4	3·08	6	0·59	6	0·17	3	0·10	2	0·03	1	1·60	3	1·39	6	1·63	5	5·02	11	18·19	60
1946	Bloemfontein	5·83	8	3·40	4	7·95	8	2·09	4	2·50	6	0·00	0	0·26	1	0·00	0	0·33	1	2·00	9	0·84	4	1·19	5	26·39	50
	Glen	6·77	11	2·26	7	3·79	8	1·49	5	2·15	9	0·00	0	0·18	1	0·00	0	0·36	2	1·74	9	1·06	5	1·05	6	20·85	63
	Brandfort	5·86	10	1·58	6	5·22	10	0·65	3	1·23	7	0·00	0	0·11	1	0·00	0	0·62·	2	2·99	11	2·78	6	1·38	4	22·42	60
1945	Bloemfontein	3·01	8	3·60	7	3·26	6	0·34	3	0·36	2	0·03	1	0·32	1	0·00	0	0·00	0	0·12	1	2·65	3	1·29	3	14·98	35
	Glen	2·44	5	2·93	8	2·99	8	0·49	4	0·18	1	0·00	0	0·15	1	0·00	0	0·00	0	0·17	3	2·58	2	1·68	5	13·61	37
	Brandfort	3·44	5	4·60	10	3·20	13	0·25	2	0·24	2	0·00	0	0·10	1	0·00	0	0·00	0	0·39	5	1·09	3	1·35	6	14·66	47
1944	Bloemfontein	3·36	5	1·05	5	2·30	11	0·35	3	0·68	4	1·56	3	0·00	0	0·00	0	4·19	2	1·84	6	2·25	9	0·63	3	18·21	51
	Glen	2·75	9	2·50	9	1·77	11	0·11	1	0·78	4	0·78	4	0·00	0	0·00	0	0·74	4	1·32	7	3·39	10	0·83	3	14·97	62
	Brandfort	1·50	9	3·62	13	3·37	11	0·32	2	0·82	5	1·02	5	0·00	0	0·00	0	0·89	6	2·19	6	4·12	13	0·70	7	18·55	77
1943	Bloemfontein	4·81	11	2·79	9	3·29	11	7·98	12	3·40	8	0·00	0	1·41	4	3·40	7	0·08	1	2·82	4	6·02	14	4·31	11	40·31	92
	Glen	2·81	9	2·81	12	2·35	10	8·32	12	3·50	7	0·00	0	1·93	5	2·42	5	0·07	1	4·80	7	6·77	15	4·86	17	40·64	100
	Brandfort	4·50	11	1·73	6	2·81	11	6·96	12	3·44	9	0·00	0	2·59	6	2·65	4	0·25	2	2·02	8	6·81	16	5·09	16	38·85	101

TABLE 3.—*Monthly and Yearly Rainfall Totals and Number of Days on which Rain fell* (contd.).

Year.	Station.	Jan.		Feb.		March.		April.		May.		June.		July.		Aug.		Sept.		Oct.		Nov.		Dec.		Total.	
		In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.
1942	Bloemfontein	2·46	9	4·58	12	3·71	14	3·58	5	0·14	2	0·06	1	0·00	0	0·84	3	0·37	2	4·04	12	3·09	7	5·50	13	28·37	80
	Glen.....	2·59	8	3·02	12	3·43	11	3·33	7	0·35	1	0·00	0	0·00	0	1·28	3	0·77	3	3·85	13	3·57	7	6·86	15	29·05	80
	Brandfort....	3·72	7	4·94	9	4·86	10	2·54	6	0·78	1	0·00	0	0·00	0	1·91	3	0·20	1	3·19	11	5·53	10	4·07	15	31·74	73
1941	Bloemfontein	2·80	8	6·86	16	0·43	1	0·72	5	0·58	1	0·10	1	0·87	2	0·00	0	0·50	1	3·35	7	0·00	0	0·58	3	16·79	45
	Glen.....	2·49	11	6·90	10	0·33	5	1·40	8	0·00	0	0·04	1	0·38	2	0·64	1	0·45	2	2·11	4	0·00	0	0·26	2	15·00	46
	Brandfort....	5·81	11	5·73	9	0·47	2	1·32	6	0·30	1	0·00	0	0·19	1	0·59	1	0·28	1	4·44	6	0·00	0	0·29	2	19·42	40
1940	Bloemfontein	0·78	4	1·91	6	4·71	8	1·33	4	1·70	5	0·28	2	0·17	1	0·00	0	2·13	8	0·36	2	5·55	6	3·15	11	22·07	57
	Glen.....	1·64	9	3·13	8	4·43	6	2·13	3	0·71	5	0·58	2	0·11	1	0·00	0	2·08	8	0·59	3	5·80	6	4·40	11	25·60	62
	Brandfort....	1·87	11	0·28	3	3·62	10	1·88	6	0·97	4	1·08	2	0·00	0	0·16	1	1·66	7	0·52	2	4·40	7	5·25	8	21·69	61
1939	Bloemfontein	5·25	8	4·13	10	1·33	6	0·53	2	0·97	3	0·00	0	0·50	3	1·95	3	0·00	0	4·12	7	4·00	5	0·75	2	23·53	49
	Glen.....	3·60	12	1·87	11	1·89	7	0·99	4	0·69	3	0·16	2	0·35	4	1·85	4	0·18	2	5·37	9	4·48	7	1·22	4	22·65	69
	Brandfort....	5·15	11	6·14	14	2·15	7	0·28	2	1·28	2	0·22	2	0·66	1	2·65	3	0·25	2	5·09	9	4·46	6	1·67	5	30·00	64
1938	Bloemfontein	3·89	8	2·10	8	1·11	5	2·90	6	0·15	1	1·08	4	0·61	2	0·65	1	0·00	0	3·31	5	2·71	4	2·41	5	20·92	49
	Glen.....	2·39	12	2·06	9	1·52	6	2·15	11	0·31	3	0·77	10	0·32	2	0·27	3	0·02	2	2·54	9	2·37	6	2·96	7	17·68	80
	Brandfort....	5·19	13	4·62	12	1·32	6	3·81	8	0·90	3	0·64	7	0·16	1	0·88	3	0·28	2	4·03	13	1·04	4	3·38	8	26·25	80
1937	Bloemfontein	5·88	11	4·65	10	2·99	5	0·00	0	0·48	1	0·00	0	0·23	1	0·00	0	0·00	0	0·40	3	2·24	5	2·65	5	19·52	41
	Glen.....	4·84	15	4·00	10	2·16	3	0·42	2	0·53	4	0·00	0	0·15	2	0·05	1	0·00	0	1·07	3	1·07	5	2·01	7	16·30	52
	Brandfort....	7·98	10	3·98	9	2·10	6	0·75	4	0·58	3	0·00	0	0·22	2	0·00	0	0·05	1	0·94	2	1·17	3	1·71	8	19·48	48
1936	Bloemfontein	3·29	8	5·46	6	6·34	9	0·71	2	0·52	3	0·00	0	0·38	2	0·00	0	0·33	3	1·43	4	5·50	10	2·30	3	26.26	50
	Glen.....	2·92	6	3·86	6	3·41	12	0·60	4	1·00	7	0·05	1	0·04	1	0·00	0	0·15	4	1·34	5	4·19	11	3·70	6	21 26	66
	Brandfort....	7·52	8	1·59	8	3·06	6	2·83	3	1·16	3	0·00	0	0·10	1	0·00	0	0·03	1	2·69	7	4·23	12	2·37	5	25·58	54
1935	Bloemfontein	1·25	4	2·94	8	4·13	7	2·18	5	1·10	3	1·10	1	0·00	0	0·61	2	0·36	1	1·93	4	2·75	3	3·78	7	22·13	45
	Glen.....	1·60	8	2·32	9	5·62	11	2·05	8	0·85	5	0·61	2	0·04	1	0·35	3	0·48	2	1·47	4	3·10	4	4·07	9	22·56	66
	Brandfort....	1·88	5	3·73	4	3·86	8	3·48	6	0·19	1	1·15	1	0·00	0	0·30	2	0·31	2	1·20	3	3·21	3	3·26	4	22·57	39
1934	Bloemfontein	5·38	10	2·69	7	2·31	9	2·13	3	2·40	4	0·00	0	0·45	1	0·10	1	0·00	0	2·46	4	2·29	4	2·65	4	22·86	47
	Glen.....	5·68	15	4·09	12	3·02	9	1·82	6	2·49	6	0·00	0	0·33	2	0·00	0	0·01	1	2·36	6	4·01	11	3·55	12	27·36	80
	Brandfort....	9·23	12	3·07	6	1·83	7	2·36	5	4·05	5	0·10	1	0·85	3	0·00	0	0·00	0	2·34	6	4·49	11	1·22	3	29·54	59

TABLE 3.—*Monthly and Yearly Rainfall Totals and Number of Days on which Rain fell* (contd.).

Year.	Station.	Jan.		Feb.		March.		April.		May.		June.		July.		Aug.		Sept.		Oct.		Nov.		Dec.		Total.	
		In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.	In.	D.
1933	Bloemfontein	0·30	1	1·42	2	1·84	5	0·95	2	0·00	0	0·00	0	0·00	0	0·20	1	0·00	0	0·40	2	5·77	13	4·76	5	15·64	31
	Glen	0·63	5	1·57	8	2·22	5	0·66	3	0·00	0	0·00	0	0·00	0	0·00	0	0·22	2	0·00	0	5·35	13	3·47	10	14.12	46
	Brandfort....	0·82	3	3·61	6	3·19	7	1·35	2	0·15	1	0·00	0	0·00	0	0·00	0	0·23	1	0·40	4	7·34	14	2·10	5	19·19	43
1932	Bloemfontein	1·94	3	2·70	7	3·12	6	0·00	0	0·00	0	0·00	0	0·00	0	0·00	0	2·90	3	1·68	3	0·58	2	2·52	3	15·44	27
	Glen	2·43	3	3·38	11	2·86	10	0·00	0	0·23	2	0·08	1	0·00	0	0·00	0	2·01	3	0·52	5	2·30	8	2·44	10	16·25	53
	Brandfort....	2·88	4	4·80	10	2·76	6	0·00	0	0·30	2	0·10	1	0·00	0	0·00	0	1·55	3	0·46	2	1·69	5	3·77	8	18·31	41
1931	Bloemfontein	6·04	11	2·31	7	2·38	6	4·30	6	0·00	0	0·00	0	2·35	4	0·00	0	0·00	0	1·60	3	3·42	6	0·52	2	22·92	45
	Glen	5·28	13	2·89	11	1·73	8	4·55	8	0·00	0	0·00	0	1·48	3	0·11	1	0·00	0	1·72	5	5·08	10	0·76	5	23·60	64
	Brandfort....	2·72	8	4·42	5	3·60	6	3·85	5	0·00	0	0·00	0	0·90	3	0·00	0	0·00	0	2·58	6	6·67	10	1·09	3	25·83	46
1930	Bloemfontein	1·92	5	2·00	4	2·52	5	2·49	4	0·00	0	0·00	0	0·00	0	0·00	0	0·00	0	0·38	2	0·40	2	1·43	5	11·14	27
	Glen	1·96	7	2·28	5	2·79	7	2·83	3	0·71	1	0·02	1	0·00	0	0·17	2	0·00	0	0·40	2	1·05	5	1·81	5	14·02	38
	Brandfort....	3·51	8	1·85	9	2·58	5	2·24	5	0·54	1	0·00	0	0·00	0	0·60	1	0·13	1	0·94	4	0·66	3	1·82	5	14·87	42
1929	Bloemfontein	2·26	4	0·48	2	4·30	11	0·55	1	0·48	2	2·06	4	0·98	2	0·47	3	3·64	10	0·67	2	1·63	4	2·99	6	20·51	51
	Glen..	1·37	4	1·38	5	5·32	12	0·34	2	0·25	3	2·01	7	1·98	2	0·31	2	4·16	13	0·53	5	1·38	8	3·75	9	22·78	72
	Brandfort....	1·82	10	1·42	3	4·85	12	0·19	1	0·87	6	1·40	6	1·80	2	0·55	2	3·51	9	0·99	2	3·05	10	4·00	11	24·45	74
1928	Bloemfontein	4·01	10	2·12	6	2·41	4	1·24	3	0·00	0	0·30	1	0·00	0	0·72	3	0·25	1	1·30	4	3·11	8	0·68	2	16·14	42
	Glen	4·32	15	2·46	9	3·19	10	1·28	4	0·05	1	0·06	1	0·00	0	0·43	2	0·23	3	1·51	5	2·64	6	1·12	5	17·29	61
	Brandfort....	5·85	14	3·53	8	2·99	9	2·39	5	0·05	1	0·00	0	0·00	0	0·15	1	0·21	3	1·43	5	1·94	5	2·45	7	20·99	58
Averages for 24 Years	Bloemfontein	3·28	7·0	2·84	7·3	3·26	7·4	2·05	4·0	0·87	2·9	0·33	1·0	0·40	1·2	0·53	1·5	0·80	2·0	1·85	4·5	2·61	5·4	2·49	5·5	21·31	49·9
	Glen	2·94	8·8	2·66	9·3	3·03	8·9	1·97	6·0	0·78	3·9	0·25	2·0	0·36	1·6	0·48	1·8	0·61	3·0	1·73	5·7	2·75	7·1	2·79	7·4	20·35	64·7
	Brandfort....	3·97	8·8	3·45	8·0	3·09	8·1	2·10	5·0	0·92	3·4	0·26	2·0	0·38	1·5	0·58	1·6	0·53	2·0	1·91	5·7	3·01	7·0	2·56	6·9	22·76	59·8

Black figures indicate the highest monthly rainfall for the year. Figures for Bloemfontein (Kings Park) and Brandfort were taken from the Reports of the Meteorological Bureau, Pretoria, and that of Glen were obtained at the Glen College of Agriculture.

There is a wide divergence of opinion as to what constitutes a dry season or month and biologists and meteorologists do not always see the question from the same point of view. According to Emberger (1952) some meteorologists regard any month in which there is less than 0·1 mm. (0·0039″) of rain as dry. Others take 1 mm. (0·039″) as the criterion. He further states that the criteria adopted by biologists vary widely; to various schools of thought a dry month is one in which the total rainfall is less than 10 mm. (0·39″), 25 mm. (0·98″), 40 mm. (1·58″) or even less than 50 mm. (1·97″). These figures are, however, of little significance if the temperature and relative humidity are not taken into account.

According to Emberger (1952), Andrews and Maze define a dry month as one in which the $\frac{\text{Precipitation (in mm.)}}{\text{Temperature} + 10^\circ \text{ (in C.)}} < 1$. At a temperature of 25 to 30° C. (77 to 86° F.) the dry months would be those with less than 35 to 40 mm. (1·38″ to 1·57″) of rain.

In plant ecology knowledge of the total rainfall is not enough. What is more important is the amount of water in the soil which is available to the plants. The effectiveness of the rainfall does not depend only on its distribution in the growing season but also upon the evaporation, temperature, penetration and soil type. The writer has observed that 1 to 2 inches (25 to 51 mm.) of soaking rain occurring in a short period (1 to 3 days) is required, in summer, to moisten an initially dry, almost flat sandy-loam soil to a depth of 12 to 24 inches, and 2 to 3 inches (51 to 76 mm.) to moisten a clayey soil to the same depth. The soil remains moist for approximately 14 days after such rain and if successive bi-weekly showers occur in amounts of $\frac{1}{2}$ to $\frac{3}{4}$ inch, a good veld growth results. Generally a summer precipitation of $\frac{1}{2}$ inch and less, occurring more or less at bi-weekly or longer intervals is of little value in maintaining the growth of the grassveld. This is especially true for veld occurring on heavy clayey soils found all along the watercourses. Because of a lower evaporation rate in autumn, the autumn rains are generally a little more effective in moistening the soil.

Plants with shallow root systems, e.g. grasses, are able to make use of small amounts of rain. Light showers falling in the dry summer months are therefore not always negligible but may have a slight ameliorating effect on the severity of a dry season. With torrential rain during the rainy season the soil is usually soaked to a great depth. After such heavy and soaking rains quite a long period will elapse before the soil again becomes dry and the plants wilt. If these soaking rains are succeeded by others within 3 to 4 weeks the veld will normaly not be detrimentally affected.

Whitmore (1950), showed that very light and moderate spring rains produce no appreciable gain in soil moisture beyond a depth of 1 or 2 inches and rains of less than $\frac{1}{2}$ inch (12·7 mm.) are of little value to agriculture. In his studies of the problems of the Drakensberg Conservation Area, Scott (1951) found that the average annual rainfall of the Highland Sourveld is 38 inches and that of the Thornveld is 26 inches. The rainfall, especially that of the Highland Sourveld, is distributed over a large number of days in small amounts of less than $\frac{1}{2}$ inch (12·7 mm.). Scott (1951), concluded that the differences in vegetation of the two veld types are presumably due to light precipitations of less than $\frac{1}{2}$ inch distributed over a large number of days per annum rather than to heavy precipitations exceeding $\frac{1}{2}$ inch. Cannon (1924), who studied the climate and vegetation of the arid regions of South Africa (Karroo and Namib desert) states that the lowest limit of effectiveness is 0·15 inch (3·8 mm.) of rain.

As has been indicated the efficacy of the rainfall is much dependent on the evaporating power of the atmosphere. Whitmore (1950), indicated that approximately 1½ to 2 inches (38·1 to 50·8 mm.) of cumulative rainfall falling in showers of effective intensity (i.e. about ½ inch per day and more) are required to moisten the initially dry soil to a depth of about two feet. As such high cumulative rain is seldom encountered in spring, the normal plant growth—especially of the shallow-rooted grasses and forbs—cannot usually commence properly before the summer.

In Table 4 the yearly rainfall and number of days with a rainfall of less than 0·01 inch (0·25 mm.), less than 0·04 inch (1·0 mm.) and of less than 0·40 inch (10·1 mm.) are recorded for the Airport, Bloemfontein, for eight years. When the yearly average is taken over the eight years, it is evident that rain was recorded for 76 days. For 55 days the rainfall was more than 0·04 inch (1·0 mm.) and for 17 days more than 0·40 inch (10·1 mm.). From these figures it can be concluded that the rainfall is distributed over a relatively large number of days per annum. For a few days only, approximately 22 per cent of the total number of rainy days, rain occurred in amounts exceeding 0·40 inch (10·1 mm.). For the average number of days in which rain occurred at Bloemfontein, Glen and Brandfort see Table 3.

Storms which cause a heavy rainfall in short periods are often encountered. Unfortunately no official rainfall data are available for individual storms of short duration. As can be seen in Table 4 the maximum rainfall recorded in 24 hours, over a period of eight years, was 4·32 inches (109·7 mm.) for the Airport, Bloemfontein.

The average annual rainfalls for Glen and Bloemfontein, over a continuous period of 31 years, and for Brandfort over 24 years, are 20·36 inches (51·71 cm.), 21·67 inches (55·04 cm.) and 22·76 inches (57·3 cm.) respectively. The average annual rainfall of Brandfort is more than an inch higher than that of Bloemfontein and more than two inches higher than that of Glen (see Table 3).

The rainfall of the area is erratic and irregularly distributed, often occurring in strips and patches. The average annual rainfall of the three stations for the past 24 years does not vary by more than approximately 13 per cent, but a greater difference in the monthly and annual distribution may be found. For instance the difference between the total rainfall of Glen and Bloemfontein, in 1949, is approximately 26 per cent (*vide* Table 3). If the total annual rainfall of Kings Park, Bloemfontein, is compared with that of the Airport, Bloemfontein (see Tables 3 and 4) it is approximately the same in certain years, e.g. in 1945, but in others, e.g. in 1942, a rather striking difference up to approximately 10 per cent is found. These two stations are situated only about 1½ miles apart. Although the total annual rainfall of Glen is the lowest of the three stations, it is surprising to see that the rain at this station occurred more or less constantly on the largest number of days, i.e. on a yearly average of 64 days in comparison to 49 and 59 days for Bloemfontein and Brandfort respectively. The low rainfall in winter occurs on a small number of days. The largest number of rainy days occurs in January, February and March (see Table 3).

Recurrent spells of drought in summer are characteristic of the central parts of the Union of South Africa. The average monthly rainfall of Bloemfontein, over 31 years, shows a clear decrease in December and February compared with November, January and March. The average monthly rainfall for Glen, over a continuous period of 31 years, shows a

TABLE 4.—*Total Yearly Rainfall* (1942 *to* 1949), *Yearly Maximum Amount of Rain recorded in* 24 *Hours, Number of Days with Precipitation* >0·01 *inches,* >0·04 *inches, and* >0·40 *inches. Relative Humidity: Airport, Bloemfontein.*

Year.	Yearly Rainfall.	Yearly Max. in 24 Hours.	No. of Days with Precipitation.			Relative Humidity.					
						Average.		Lowest.		Highest.	
			> ·01 in.	> ·04 in.	> ·40 in.	9.30 a.m.	3 p.m.	9.30 a.m.	3 p.m.	9.30 a.m.	3 p.m.
1949.....	17·71	1·57	68	57	15	62	31	49	24	76	43
1948.....	19·88	2·50	62	38	13	63	35	37	18	82*	59
1947.....	19·27	1·70	69	48	18	59	34	45	24	70	40
1946.....	26·02	3·09	80	58	17	63	38	42	24	80	50
1945.....	14·90	1·75	53	37	14	53	29	36*	18	74	47
1944.....	17·83	4·32*	77	55	10	62	34	41	17*	81	58
1943.....	38·93	2·11	106	84	33	73	48	62	36	84	62*
1942.....	25·72	1·53	100	70	22	66	38	53	30	79	51
Average for 8 years.....	22·53	—	76·8	55·9	17·8	62·6	35·9	—	—	—	—

Figures for Table 4 were taken from the Reports of the Weather Bureau, Pretoria. Figures of relative Humidity were taken at 8 a.m. and 2 p.m. in 1948 and 1949; the lowest and highest figures are marked (*).

decrease in February but not in December (see also Table 3). The annual average rainfall of Brandfort, over 24 years, shows a decrease in December but not in February.

In Table 5 the mean rainfall with the monthly range is indicated for Bloemfontein and Glen for 31 years. It is clear that the average rainfall is not only small in winter but that its monthly range is much smaller than that of the summer. This range is, for instance, from 0·0 to 1·8 inches (0 to 49·2 mm.) in July and from 0·63 to 6·77 inches (16·0 to 171·9 mm.) in January for the Glen station.

TABLE 5.—*Mean Rainfall in Inches and Variation in Rainfall, Bloemfontein (Kings Park) and Glen for* 31 *Years*: (1921 *to* 1951), *October to September.*

Month.	Station.	Mean Rainfall, Inches.	Limits of Variation in Inches of Rain.	
			Lower.	Upper.
October	Bloemfontein	1·70	0·12	4·12
	Glen	1·64	0	5·37
November	Bloemfontein	2·58	0	6·02
	Glen	2·68	0	6·77
December	Bloemfontein	2·49	0·15	5·50
	Glen	2·75	0·11	6·86
January	Bloemfontein	3·38	0·30	8·09
	Glen	3·08	0·63	6·77
February	Bloemfontein	2·99	0·48	8·22
	Glen	2·61	0·76	6·90
March	Bloemfontein	3·51	0·43	8·36
	Glen	3·31	0·33	8·23
April	Bloemfontein	1·96	0	7·98
	Glen	1·81	0	8·32
May	Bloemfontein	1·00	0	3·62
	Glen	0·76	0	3·50
June	Bloemfontein	0·38	0	2·68
	Glen	0·30	0	2·10
July	Bloemfontein	0·35	0	2·35
	Glen	0·34	0	1·98
August	Bloemfontein	0·52	0	3·40
	Glen	0·42	0	2·97
September	Bloemfontein	0·81	0	4·19
	Glen	0·66	0	4·16
YEARLY TOTAL	Bloemfontein	21·67	11·66	39·79
	Glen	20·36	9·37	38·49

Because of erratic rainfall, high temperatures and evaporation, spring is the most critical period for plant growth and for crop and livestock production. It often happens that light spring rains are followed by long intervals of drought so that the grass which has been stimulated to sprout, wilts and dies off. Wilted spring grazing may cause prussic acid poisoning in cattle and sheep.

3. HUMIDITY.

Records of the relative humidity at 9.30 a.m. and 3 p.m. are available for the Airport station, Bloemfontein, and for Glen College of Agriculture. In Table 4 the average yearly humidity is recorded for the Airport over eight years. The dry and desiccating western winds which usually prevail in spring and early summer are always accompanied by sudden drops in humidity.

4. EVAPORATION.

No evaporation figures are available for the area studied. Whitmore (1950), states that at all the stations recording evaporation in the Orange Free State it was found that evaporation is greatest during spring and early summer, which is the most critical period for the growth of summer cereals.

5. WINDS.

Detailed records of surface winds are available at the Airport station, Bloemfontein. At this station wind velocities are measured by means of a Dines Pressure Tube Anemometer and the frequencies are derived from anemograms which are taken hourly.

Wind is important in increasing the evaporating power of the air and therefore in the acceleration of plant transpiration. According to Tidmarsh (1948), records at Middelburg, Cape, indicate that the western winds have, in latter years, increased both in velocity and frequency. He further states that the winds from the western quadrant " although markedly a winter phenomenon, are in truth still important winds of the summer months, attaining frequencies of 20 per cent and over as deep into the summer as December and January."

In Table 6 the wind frequencies for 1948 are given for the Airport, Bloemfontein. In general there is no very great difference between the figures of this year and those of the previous and succeeding years. From this table it is clear that winds in the north-western quadrant predominate through the year, constituting approximately 50 per cent of the directional frequency. Approximately 20 per cent prevail in the south-eastern quadrant. Although there are occasional strong winds, approximately 90 per cent of the winds have a low velocity of 15 miles per hour or less.

TABLE 6.—*Wind Frequency for* 1948. *Airport, Bloemfontein.*

Month.	Wind Frequency nD.								
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
January	147	91	37	26	10	43	77	126	187
February	105	95	29	34	44	33	41	87	228
March	110	100	55	34	36	52	63	76	218
April	103	60	58	55	44	86	84	124	106
May	94	69	54	27	42	75	89	79	215
June	91	69	78	33	39	83	94	81	152
July	175	87	76	38	25	54	74	102	113
August	106	55	38	41	59	99	105	111	130
September	94	44	33	36	49	83	156	124	101
October	103	71	37	53	60	109	118	111	82
November	105	82	25	35	62	87	127	143	54
December	62	49	34	36	42	135	172	145	69
TOTAL	1,295	872	554	448	512	939	1,200	1,309	1,655

Figures for Table 6 were taken from the report of the Weather Bureau, Pretoria.

Generally autumn is the calmest season of the year and spring and early summer the most windy. The winds at the beginning of the summer of the north-western quadrant often cause dust storms, which are followed by thunderstorms.

CHAPTER 3.

AN OUTLINE OF THE VEGETATION TYPES OCCURRING IN THE BLOEMFONTEIN–BRANDFORT AREA.

The vegetation of the area studied is rather uniform and the different vegetation types are rarely sharply delimitated.

A.—THE AQUATIC AND SUB-AQUATIC VEGETATION.

(*Vegetation of Streams, Dams, Pans, Wet Vleis and Regularly Flooded Situations.*)

As there are few dams and weirs and few large bodies of permanent water, true hydrophytes are poorly represented. The vegetation occurring in the dams, pans, vleis, along stream-edges, etc., is subjected to periodic droughts and is generally more mesophytic than hydrophytic.

B.—VALLEY ACACIA BUSH COMMUNITY.

All along the valleys, especially along the Modder River and larger spruits, heavy turfy and alluvial soils occur which are covered by three vegetation communities:—

(*a*) The *Acacia Bush Community*,

(*b*) *Valley-Vlei Grassveld*,

(*c*) *Ganna Community*.

These communities are determined principally by water conditions. On the banks of the watercourses and lower parts of the valleys—especially on places where water accumulates above or underground—the Valley Acacia Bush community occurs, with heliophilous species between the trees.

On low-lying and well-drained places, e.g. in depressions where water accumulates without the soil's becoming water-logged, the Valley-Vlei Grassveld community is found. On the higher and drier places, and where little water penetrates and a high run-off occurs, the Ganna community is encountered. These latter situations are too dry for grasses to thrive and only highly adapted drought-resistant plants, showing affinities with those of the Karroo, occur.

C.—RANDJIE VELD.

(*Vegetation of the Hills, Ridges and Koppies.*)

On the steep slopes of the hills, strewn with boulders and rocks, the vegetation consists of a mixture of trees, shrubs, grasses and forbs. The vegetation on some of the ridges directly north of Bloemfontein consists of typical karroid plants and differs markedly from the vegetation on other ridges occurring in this area. Generally a marked difference exists between the vegetation on the northern and western slopes and that on the southern and eastern slopes of the large hills.

D.—GRASSVELD.

Grassveld is the most extensive veld type in the area. It occurs on raised ground (bults), plains and parts of the valleys, and occupies approximately 70 per cent of the total area. The grassveld may be divided into three types, namely:—

(*a*) *Valley-Vlei Grassveld,*

(*b*) *Themeda Grassveld,*

(*c*) *Kalkveld.*

It is mainly differences in soil that determine the distribution of these grassveld types. As has been indicated, the Valley-Vlei Grassveld occurs on heavy soils where water accumulates. Themeda-veld occurs typically on raised ground, flats and plains and is the most extensive. It occurs on sandy loam as well as on turfy soils. On limestone outcrops and bults, Themeda-veld is replaced by a typical Kalkveld community. As limestone outcrops generally occur here and there only, the Kalkveld occupies little of the area.

CHAPTER 4.

CONCEPTS AND METHODS OF PASTURE ANALYSIS.

It was decided that in addition to a descriptive account of the vegetation some fundamental characteristics of the communities, especially of the grassveld, should be given. The choice of methods for botanical analysis is determined by the purpose of the study and by the nature of the vegetation. Because of differences in topography of the terrain and in the composition of the vegetation types, it may not always be possible to adhere to one method of analysis throughout a botanical survey.

The works of the following ecologists were consulted: Braun Blanquet (1932), de Vries (1948), Bruijns (1947), Hanson (1938, 1950), Weaver and Clements (1929, 1938), Meltzer (1944), Oosting (1950), Brown (1954), and in the Union those of Archibald (1952), Tidmarsh and Havenga (1955), von Broembsen (1952), West (1937, 1949), Louw (1951), Story (1952), Potts and Tidmarsh (1937), Brynard (1953), Murray (1946), and others.

Except where otherwise stated, the surveys described in this paper were done by the Wheel Point method of Tidmarsh and Havenga. The diameter of the spokes of the wheel used is $\frac{1}{2}$ inch. The writer strictly adhered to the definition of a strike and a miss as given by the authors. The Wheel Point apparatus could not be used on the koppies, hills and ridges because of the steepness and rockiness of the slopes. The botanical surveys on the ridges were therefore made more or less according to the Estimated Frequency List method which has been used extensively by Acocks (see also Murray, 1946). Instead of the abbreviations used by Acocks, figures are used by the writer. In this method top and basal points on the ridges were marked and a straight steady walk was taken from the bottom to the top so that, as far as possible, a straight line of survey was obtained. All the plants occurring on a narrow strip of ground, approximately 3 to 4 feet wide, were recorded and an estimate of their frequency was made according to the following scheme:—

Very abundant.....	Plants less than six inches apart, Symbol 8.
Abundant.....	Plants less than one foot apart, Symbol 7.
Common.....	Plants less than two feet apart, Symbol 6.
Frequent.....	Plants less than 10 feet apart, Symbol 5.
Fairly frequent.....	Plants less than 25 feet apart, Symbol 4.
Occasional.....	Plants less than 100 feet apart, Symbol 3.
Rare.....	Plants less than 200 feet apart, Symbol 2.
Very rare.....	Plants more than 200 feet apart, Symbol 1.

This Frequency List method gives the estimated average distance between the plants of each species. Of grasses, forbs and shrubs more or less 10 plants were taken, and of rare plants and of trees all that could be seen and properly identified from the line of survey. With this method, which is admittedly considerably less accurate than the Wheel Point method, hills and koppies near Glen and Karree and a ridge near Mazelspoort were surveyed (see Chapter 7).

The following method of survey was used in the study of plant retrogression and succession in the grassveld (see Chapter 9):—

(1) A representative sample of grassveld was chosen (usually one or more morgen in extent) and the names of all the species seen in it were written down. This was continued until the most abundant species were determined. An estimate was then made of the basal cover or the abundance of the individual species. Often the frequency of the most common species was ascertained and recorded.

(2) A charting method was used to depict the vegetation on three quadrats (see Chapter 9). Three quadrats, each one yard square, were chosen and the vegetation in the quadrats was mapped by hand on squared paper.

From the completed maps a clear picture can be formed of the size and distribution of the different constituting species.

As the construction and interpretation of these charts requires much time this method is not recommended where successional studies are made on large areas.

In the Wheel Point method species occurring in small numbers in a community are often not recorded so that for a complete survey additional notes and lists are essential. Such rare species may nevertheless be important for the characterisation of a community. For sociological studies and comparisons, complete plant lists should therefore be compiled to supplement the records of the Wheel Point method.

If the Wheel Point method is used for determinations and comparisons of the basal cover of different plots, it is not necessary to use equal areas or to take an equal number of points. If, however, the species composition of various plots is to be compared, species lists should be drawn up from areas equal in size. As this was not realised at the time of the first application of the Wheel Point method, surveys of existing camps of different sizes were made and for species composition the results were not always comparable.

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CHAPTER 5.

THE AQUATIC AND SUB-AQUATIC VEGETATION.

(*Vegetation of Streams, Dams, Pans and Wet Vleis.*)

True hydrophytic communities are poorly represented throughout the area studied, for except for Mockesdam and the Mazelspoort weir in the Modder River, which have permanent water, almost all the other dams and weirs dry up frequently, and true aquatic plants usually require perennial streams or permanent pools. The vleis and streambanks have also been changed by farming practices. Not only has soil erosion become pronounced but the vegetation has been destroyed in many places. On isolated spots on the banks of the river and local spruits, especially in protected places, the remnants of a former more luxuriant vegetation can be seen consisting principally of sweet perennial grasses.

The hydrophytic communities can best be studied in the Modder River and the Rhenostersprui t where weirs are present. Different hydrophytic species are most conspicuous and quite richly represented just below the weirs, where there is continual seepage. Specially at Mockesdam, and even along the Modder River, large amounts of soil debris have collected on islets and alluvial banks, on which aquatic and semi-aquatic plants are well represented.

1. SUBMERGED ALGAE.

Submerged Algae, usually filamentous types, are common in shallow stagnant pools and ponds, or in slow moving streams. Unicellular Algae are also present but are not conspicuous. The filamentous Algae are usually present in thick floating masses in the water but may also be submerged and may partly fill the pools they are in. They may also be anchored to the muddy substratum. These masses of vegetation help a great deal in reducing the velocity of the shallow streams and in holding silt and thus building up the bottom of the pools, especially where they occur in slow moving water. As these plants die off a certain amount of organic material is released.

After heavy rains received in April, 1953, a species of *Hydrodictyon* and a species of *Chara* were found in a pool on a bult at Glen. This pool is usually dry during winter and in droughts. As the former species was found only this once it must be considered as rare in the area studied.

2. FREE-FLOATING AQUATICS.

With the exception of *Lemna minor* no free-floating hydrophytes have been found in this area.

Lemna minor is a minute gregarious floating aquatic and consists of a short axis and 2 to 3 leaves. It has one small rootlet, approximately half an inch long. It forms beautiful light green mats in stagnant pools, sometimes so dense that a large part of the surface of the water is covered. This aquatic is encountered only in the Rhenostersprui t at Bloemspruit, where it thrives in more or less permanent stagnant pools. Although this plant has been washed down the spruit several times it does not seem to thrive in pools in the lower part of the spruit or in the Modder River.

If these pools in the Rhenosterspruit dry up, *Lemna minor* disappears but reappears very soon after the water supply has been replenished. It remains green throughout the year and multiplies much more slowly in winter than in summer.

It has not been possible to ascertain the details of the ecological and chemical requirements of this aquatic. The undermentioned ecological conditions are obvious in the Rhenosterspruit where this plant thrives, and it is possible that they do not all exist in the Modder River and other watercourses:—

(1) The weir and the pools in the Rhenosterspruit, at Bloemspruit, retain a water supply more or less permanently throughout the year. This is an ideal habitat for Lemna.

(2) The Rhenosterspruit, at Bloemspruit, is approximately 20 feet deep by 40 to 50 feet wide, and its banks are densely covered by vegetation, especially by the planted weeping willows. During summer the long branches of these willows cast a light shade on the water which seems to be beneficial to the growth and development of Lemna. The bright summer sunlight seems to be detrimental to its growth and development. These shaded conditions are not so evident in the Modder River and in many other spruits in this area because they are generally wider.

(3) The Rhenosterspruit does not drain as large an area as the Modder River and is not very often flooded. Moreover this spruit, when in flood, does not flow as fast as the river. For its growth and multiplication Lemna requires stagnant pools and quiet atmospheric conditions, and this habitat is best represented in the Rhenosterspruit. During floods practically all the plants are washed down the spruit but those remaining show a remarkable power of recuperation and multiplication and cover great parts of the surface of the pools again in a matter of 4 to 5 weeks in summer.

(4) The bed and sides of this spruit are muddy and contain much organic material and every year a large amount of the leaves of the deciduous trees is turned into humus on the spruitbanks. The silt content of the water is low.

The influence of organic matter on the growth and reproduction of *Lemna minor* and *L. major* has been studied in detail by Clark and Roller (1930). They found that organic matter and micro-organisms are very important for the growth and multiplication of these plants. The high organic matter content in the water of the Rhenosterspruit undoubtedly plays an important rôle in the growth and stimulation of *L. minor*.

Water pumped from the weir in the Rhenosterspruit usually contains a large amount of Lemna. It collects in great masses on the water surface of reservoirs, decays, and is removed and occasionally used as compost.

L. minor seems to have a limited distribution in the Orange Free State as well as inland in South Africa. It was not recorded in the Potchefstroom, Kroonstad and Weenen areas (Louw 1951, Pont 1932 to 1935, West 1949). Weintroub (1933) found it in pans of the East Rand and the writer also observed it in a lake at Bethlehem.

3. ROOTED SUBMERGED AND FLOATING AQUATICS.

(*a*) Rooted Aquatics with Floating Leaves.

Because of the absence of permanent streams, submerged hydrophytes anchored to the substratum with leaves floating on the water surface are uncommon. Only three species, namely *Potamogeton nodosus*, *Polygonum amphibium* and *Marsilea* sp. (prob. *M. macrocarpa*) occur in the area. The two last-named species occur in streams but are very rare. *P. nodosus* is well represented along the margins of dams and pools. It may occur also on the higher margins of the beds of dams and pools which are only occasionally flooded, but in these situations the growth is stunted. No water lilies (*Nymphaea* spp.) were observed in this area.

(*b*) Rooted Submerged to Floating Aquatics.

The more or less submerged *Potamogeton crispus* is rather rare and was found only in pools in the Modder River. *P. pusillus* is common and widely spread in pools and dams as well as in streams. It is often dominant in pools and may form such masses that the whole water surface may be covered. Parts of this plant may be submerged and the rest floating. It is a good soil protector and an important pioneer on the margins of dams and pools. *Crassula natans* grows commonly in the bed of the Modder River valley, especially in smaller watercourses, streams and boggy situations. It forms thick submerged and floating masses, is an efficient soil binder and reduces the velocity of small streams.

Lagarosiphon muscoides is also encountered somewhat rarely in dams and pans.

Ranunculus drouetii occurs also rarely, in the Modder River.

Nasturtium officinale shows quite a remarkable adaptation to different habitats. Generally it is confined to streams and pools and in these situations occurs as a true aquatic, floating on the water surface and rooted in the substratum. In some localities, however, it has been found at the edges of streams and vleis which are only occasionally flooded. When exposed to droughts it is stunted. *N. elongatum* may occasionally be encountered as an aquatic, especially at stream edges.

The floating hydrophytes are poorly represented not only in this area but also over the whole plateau of South Africa (Louw 1951) and in parts of Natal (West 1949).

4. REED-SEDGE COMMUNITIES.

The reedswamp vegetation is best represented in the bed of the Modder River and the lower portions of the Rhenostersprui where big pools exist. The river is narrow, with steep banks; there is no definite zonation of the vegetation and the distribution of the reeds and sedges on the banks of streams is very erratic.

Phragmites communis is a robust plant, 5 to 10 feet tall and occurs abundantly on the banks of the Modder River, in spruits, and less frequently in vleis. It thrives in water three feet deep and may also be encountered on dry spots which are only occassionally flooded. On small

islets in the Modder River this species is very conspicuous and if sufficient moisture is present the whole islet is invaded. Because of its vigorous rhizomatous habit it is a valuable soil binder, protecting the river banks against erosion. It usually has no associated species except occasionally *Cyperus marginatus*. *Phragmites communis* is used by Natives and Europeans for building and thatching purposes.

Cyperus marginatus is frequent on the margins of streams and in vleis. Although it may grow in shallow water it is most common on stream banks where it forms a dense luxuriant stand.

Cyperus longus grows occassionally in dense patches on the stream edges of the Modder River and Rhenosterspruit. It also is a robust stoloniferous species attaining a height of four feet. It favours shallow water and is occasionally associated with *Cyperus marginatus*. Being taller and more prolific it seems to displace *C. marginatus* in certain situations.

The stoloniferous *Typha australis* occurs occasionally in the beds of spruits or on the edges of water furrows but has not been observed in the Modder River.

5. SEMI-AQUATIC VEGETATION.

Where the habitat on the banks of the watercourses becomes drier the reed-sedge vegetation is replaced by other semi-aquatic species. Vleis, dams, pools and local pans are the typical habitats for these semi-aquatics.

(*a*) Zonation in Dams and in the Modder River.

The zonation and distribution of the most important hygrophilous species occuring on the edges of two dams were studied. (See Figures 1 and 2).

The dam depicted in Figure 1 is near the poultry section on the farm of the Glen College of Agriculture. Only *Potamogeton nodosus* occurred in permanent water area. In the distribution of the hygrophilous species at least three distinct zones can be distinguished:—

(*a*) The inner zone, i.e. the area surrounding the more or less permanent water level, is occupied by two hygrophilous communities, viz. the *Polygonum plebium* and the *P. lapathifolium* community, the former in the area nearest to the dam wall. The prostrate hygrophilous *Amaranthus thunbergii* and the short, matted *Limosella longiflora* are typically associated with *Polygonum plebium*. *Potentilla supina* is typically associated with *Polygonum lapathifolium*.

(*b*) The intermediate zone consists of a dense mixture of *Polygonum plebium*, *P. lapathifolium* var. *glabrum* and *Cyperus marginatus*. On the small open spaces *Potentilla supina*, *Paspalum distichum* and *Polygonum aviculare* are found. The intermediate zone is a conspicuous, erect, dense vegetation attaining an average height of 15 inches.

(*c*) The outer zone consists of mesophytic species which are less robustly and densely developed than in the intermediate zones. They are more or less matted or prostrate and attain an average height of six inches. *Senecio reptans* and *Chenopodium glaucum* are dominant. *Helichrysum declinatum*, *Atriplex* sp., *Elymus canadensis*, *Venidium arctotoides* and *Potentilla supina* are the most common associated species. The outer zone is surrounded by the *Acacia karroo* community.

The distribution of the hygrophilous species on the edges of a dam on the farm Bishop's Glen is shown in Figure 2. This dam is situated approximately one mile east of the Glen railway station. No species were found in the deepest part of the dam. Scattered floating patches of *Potamogeton pusillus* were, however, found in water 1 to 2 feet deep. The inner zone, adjacent to the more or less permanent water level, is covered by a pure, rather dense stand of *Polygonum aviculare*. The intermediate zone consists of a dense mixture of at least five species. *Polygonum lapathifolium* var. *glabrum* and *P. aviculare* dominate. *Limosella longiflora* and *Paspalum distichum* occur here and there as dense patches. *Brassica strigosa* is scattered throughout this zone. The outer zone consists of *Diplachne fusca* which forms a dense cover. The small open spaces between the grass tufts are occupied, to a great extent, by the erect weed *Nidorella resedaefolia*. *Panicum stapfianum* occurs most abundantly in the eastern part of this zone. The outer zone is surrounded by a *Themeda-Panicum stapfianum* community.

If the three zones of the two dams studied are compared the following is evident:—

(1) The inner zones are entirely different.

(2) The intermediate zones show a striking similarity. Three species characteristic of dam edges, viz. *Polygonum lapathifolium* var. *glabrum*, *P. aviculare* and *Paspalum distichum* are common in both. The bright yellow-flowered *Brassica strigosa* is characteristic of dam margins but is never a dominant.

In the larger spruits and the Modder River, with steep banks, the semi-aquatic plants are restricted to narrow strips on either side of the streams and pools.

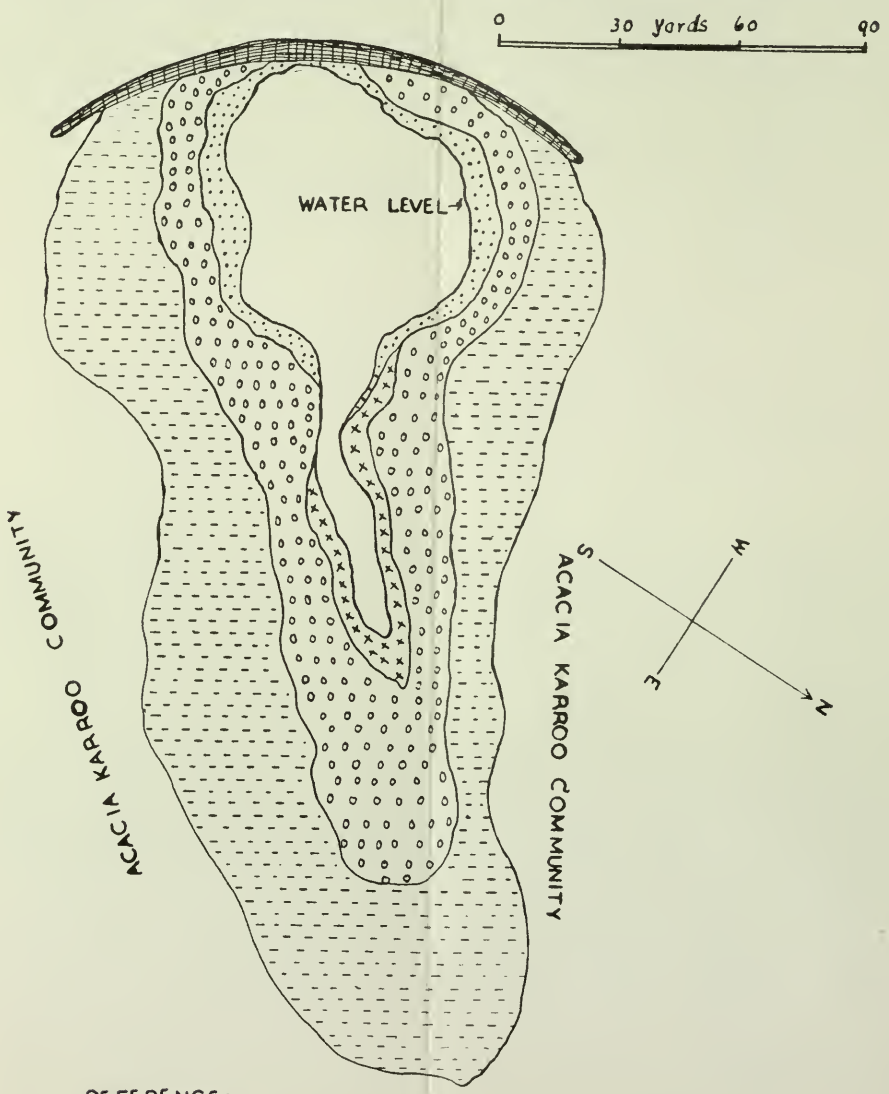
In Figure 3 which represents a cross section of the Modder River, near a homestead in camp SR. on the farm of the Glen Agricultural College, the distribution and zonation of the most common hygrophilous species are shown. This portion of the river is dammed up and the more or less permanent water level is shown.

Phragmites communis forms dense stands on the lower wet parts of the steep banks. It is usually restricted to the area near the water level. It thrives in water three feet deep as well as on higher situations approximately 10 to 15 feet from the permanent water level. The higher and drier part of the streambanks is covered by grasses, e.g. *Eragrostis nebulosa*, *Eragrostis* sp., *Cynodon dactylon*, the hygrophilous *Equisetum ramosissimum* and weeds. The upper parts of the streambanks as well as the lower parts of the valley are surrounded by a dense *Acacia karroo* community in which *Rhus pyroides* is rather common and conspicuous.

A general characteristic of the semi-aquatic plants is that they are rhizomatous or stoloniferous, and root copiously at the nodes. They form a sod-like mat of vegetation which collects silt and effectively checks soil erosion.

FIGURE 1.

ZONATION OF THE VEGETATION ON THE EDGES OF A DAM AT THE COLLEGE OF AGRICULTURE, GLEN, 15-1-1954.



FOLDOUT BLANK

FIGURE 2.

ZONATION OF THE VEGETATION ON THE EDGES OF A DAM ON THE FARM BISHOPS GLEN, 14-1-1954.

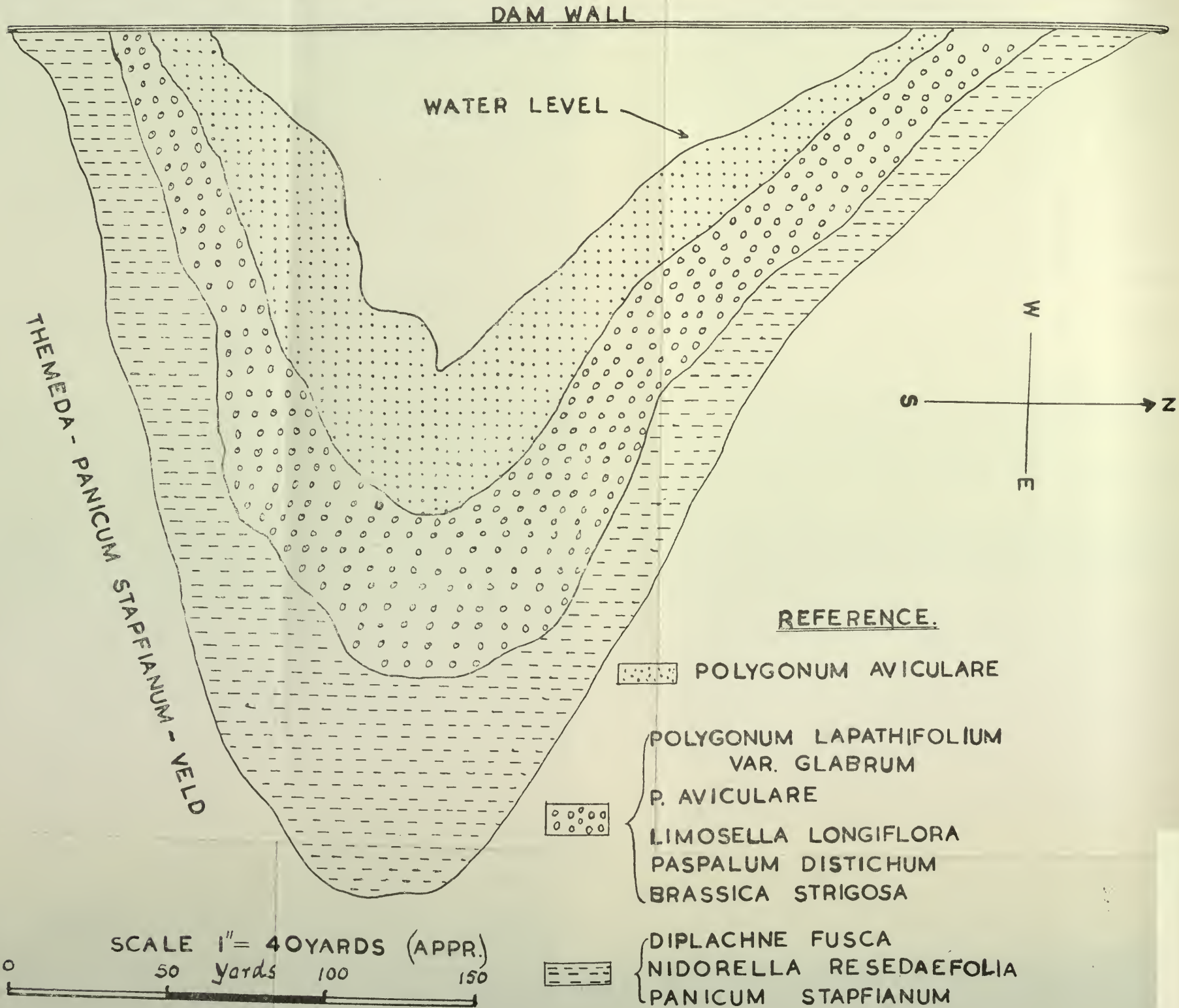
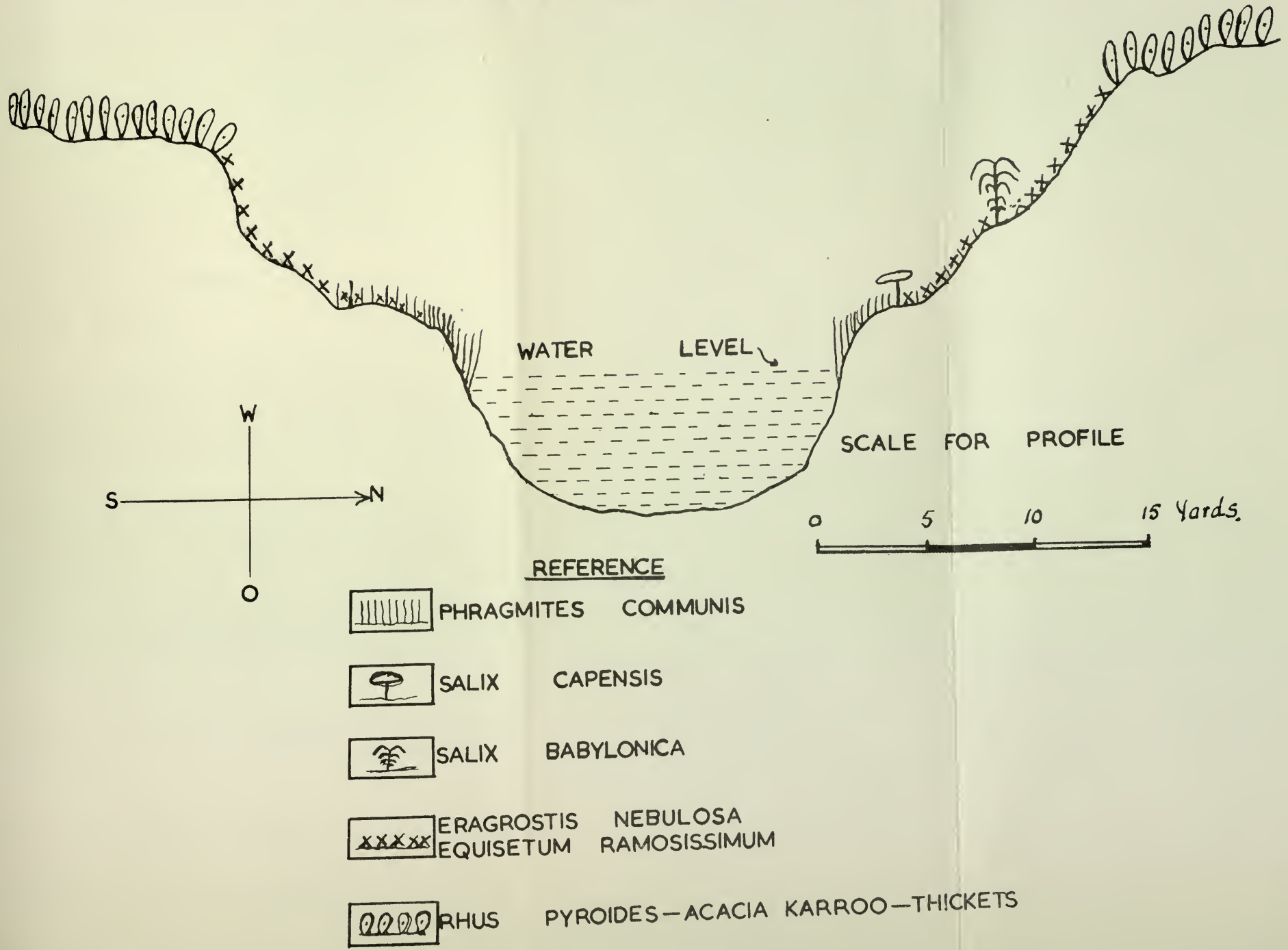


FIGURE 3.

CROSS SECTION OF THE MODDERRIVER AT GLEN SHOWING THE ZONATION OF THE VEGETATION, 18-1-1954.



(*b*) Common Semi-Aquatic Species of Dam Edges and Wet Vleis.

The semi-aquatic vegetation of vleis and low streambanks is characterised by a variety of grasses and sedges. The following are some of the more common, arranged more or less in order of abundance:—

Grasses.	*Sedges, etc.*
Hemarthria altissima.	*Equisetum ramosissimum.*
Paspalum distichum.	*Cyperus marginatus.*
Diplachne fusca.	*Cyperus longus.*
Phragmites communis.	*Juncus exsertus.*
Agrostis lachnantha.	*Cyperus* sp.
Eragrostis nebulosa.	*Carex vulpina.*
Eragrostis plana.	*Scirpus dioecus.*
Bromus catharticus.	*Scirpus fluitans.*
Eragrostis micrantha.	*Eleocharis palustris.*
Sporobolus iocladus.	
Eriochloa fouchei.	
Hordeum chilense var. *compressum.*	
Echinochloa spp.	
Helictotrichon turgidulum.	

(*c*) Trees in the Modder River.

The banks of the Modder River support the two willow species *Salix capensis* and the exotic *S. babylonica*. The former prefers the bed of the river and frequently grows on the river islets. The latter is usually confined to the banks of the river near the water level. Both species are ornamental in summer.

In many places semi-aquatic plants are replaced by the willows which are taller and grow much more quickly. They tolerate water-logged soil and temporary inundation, and have extensive root systems which enable them to stand against floods. As the Modder River is a fast flowing stream old trees are usually broken during high floods but the younger trees bend readily without damage.

Pont (1934) describes and illustrates the phenomenon of inverted polarity in *Salix babylonica*. He discusses the circumstances under which this takes place and states that it may also be observed near Bloemfontein in the Modder River. The writer, however, did not find an example of this.

These trees often attain a height of 30 feet and with their extensive root system they help to stabilize the streambanks. Furthermore they produce shade during summer for a number of sciophilous plants, e.g. *Poa annua*, *Bromus* spp.

6. THE MAIN DIFFERENCES BETWEEN THE FLORA OF THE STREAMS AND VLEIS IN THE BLOEMFONTEIN–BRANDFORT AREA AND THAT IN THE POTCHEFSTROOM AREA.

The Bloemfontein–Brandfort and Potchefstroom areas form part of the great inland plateau of South Africa and lie, more or less, on the same longitude. The Potchefstroom area is about two degrees to the north.

The vleis in the Potchefstroom area are more extensive than those in the Bloemfontein–Brandfort area, and the vegetation of the streams, vleis and watercourses of the two areas show the following differences:—

(*a*) The Mooi River in the Potchefstroom area is a perennial stream fed by strong springs. As a result floating aquatics characteristic of running water are more common in the Potchefstroom than in the Bloemfontein–Brandfort area. The following species occur in the former and are absent from the latter:—

Riccia fluitans var. *aquatica* L., *Nymphaea spectabilis* Gilg., *N. nelsonii* B. Davy, *Ludwigia palustris* Ell., *Potamogeton schweinfurthii* A. Benn. and *Lagarosiphon major* (Ridl.) Moss.

The free floating aquatic *Lemna minor* was found in the Bloemfontein–Brandfort area only.

(*b*) The following hygrophilous species in the Potchefstroom area are not found in the Bloemfontein–Brandfort area: *Cladium mariscus* R. Br., *Potamogeton pectinatus* L., *Aponogeton spathaceum* E. Mey., *Leersia hexandra* Sw., *Miscanthidium junceum* Stapf, *Arundinella ecklonii* Nees and *Eragrostis namaquensis* Nees var. *robusta* Stapf.

In an interview Mr. J. P. H. Acocks stated that the first three grasses have a wide distribution throughout the Union of South Africa. They are, however, most abundant in the eastern high rainfall parts of South Africa. *E. namaquensis* var. *robusta* is rather rare and occurs most abundantly in the Griqualand West area.

(*c*) In the Potchefstroom area *Scirpus corymbosus* Roth. is a conspicuous member of the reed swamp vegetation. It was not found in the Bloemfontein–Brandfort area but its place is taken to a certain extent, by *Cyperus marginatus.*

(*d*) *Typha australis* is absent from the Vaal River in the Potchefstroom area but flourishes all along the Mooi River. In the Bloemfontein–Brandfort area it is absent from the Modder River but thrives in wet vleis.

(*e*) In the Potchefstroom area *Equisetum ramosissimum* was found to be indifferent to soil type but in the Bloemfontein–Brandfort area it was encountered on sand banks only.

(*f*) There are more species of *Juncaceae* in the Bloemfontein–Brandfort area (six species) than in the Potchefstroom region (three species).

(*g*) There is a marked similarity in the flora of the Modder River and that of the Vaal River (Potchefstroom area) which are both fast flowing. Their vegetation differs markedly from that of the Mooi River (see Louw 1951).

7. NOTES ON THE FLORA OF STREAMBANKS, DAMS, PANS, WET VLEIS, REGULARLY FLOODED SITUATIONS AND IRRIGATED LANDS.

In the foregoing discussion a number of the most conspicuous semi-aquatic species has been mentioned. Many others occur, however, on streambanks, in dams, pans, wet vleis and lands which are subjected to periodic inundation. The floods are usually encountered in summer and autumn and are often followed by severe droughts lasting several months.

The vegetation which is characteristic of these situations must, therefore, be able to tolerate wetness and drought. Furthermore high temperatures are usual during summer and plants requiring continuous wet and/or shady conditions, e.g. *Crassula natans*, *Ranunculus drouetii*, etc., are unable to inhabit these situations successfully. Plants growing there are usually also exposed to sevère grazing and trampling.

The following are the most characteristic of the Pteridophyta and of the Phanerogams. The families are arranged according to Phillips (1951).

(*a*) Equisetales.

Equisetum ramosissimum is a common pioneer on the sand banks, islets, and streambanks of the Modder River. It occasionally forms thick patches with an average height of two feet.

(*b*) Monocotyledonae.

Graminae.

Grasses and sedges form the most important plant constituents of the vlei and stream flora. Many grass species and a few sedges show a great degree of adaptability in their water requirements. Many of the hygrophilous grasses are stoloniferous or rhizomatous and form thick mats. Almost all these grasses are palatable, have a low fibre content and are of great grazing value, especially during droughts and in winter. Among the most important are *Hemarthria altissima* which occurs frequently in the streambeds, wet vleis, and in moist flushes. It has long, robust, prostrate stems rooting at the nodes to form dense mats. *Imperata cylindrica* is a rare unpalatable stoloniferous species. It prefers moist streambanks and forms dense patches. The palatable *Paspalum dilatatum* and *P. distichum* are common acclimatised exotic species; the latter forms a very dense cover on streambanks, while the former is common on irrigated lands and forms strong tussocks. *Eriochloa fouchei* is an important annual found only in wet places and regularly irrigated lands. It is prostrate and affords good summer grazing. All four species of *Echinochloa*, i.e. *E. colona*, *E. stagnina*, *E. crus-galli* and *E. holubii* are hygrophilous, the first three usually occurring as pioneers on wet bare places. *E. crus-galli* is very robust though relatively rare while *E. holubii*, which is one of the most valuable grazing grasses found in South Africa, is a palatable stoloniferous grass which may form thick isolated stands in the beds of spruits and may reach a height of five feet. *Agrostis lachnantha* prefers moist streambanks and furrows but may also be found on drier shady habitats. *A. semiverticillata* is hygrophilous and plays an important rôle in colonising sandbanks in the Modder River. This grass is prostrate and forms dense mats. *Diplachne fusca* is one of the most common but unpalatable vlei grasses. It may form close patches on the sides of dams and is often associated with *Polygonum* spp. It is interesting to note that the stoloniferous *D. fusca* var. *stolonifera* is tolerant to salt water and grows commonly in the salt pools at Saltpan where it is dominant. It has not been recorded elsewhere. *Hordeum chilense* var. *compressum*, an exotic species, is well acclimatised and common on irrigated fields on the sewage farm at Bloemfontein. It is a good pasture grass and has a high carrying capacity. The exotic prostrate perennial *Elymus* sp. shows a strong demand for water and is common on irrigated lands and poorly drained water-logged depressions.

Species typical of moist situations such as streambeds, water furrows, etc., but not showing a special preference for aquatic conditions, are usually strongly tufted perennials and include some of our best fodder and grazing grass types.

Andropogon appendiculatus is a valuable gregarious grass and forms thick mats in the beds of spruits and vleis. Although it may also be encountered on stream edges it prefers watercourses which are often flooded (see also Chapter 8). It is rather uncommon and because of its palatability it is usually the first grass to be selected by cattle. *Panicum coloratum*, *P. deustum* and *Urochloa pullulans* (rare) are broad-leaved summer growing species occasionally found in dry beds of spruits. The exotic winter grasses *Bromus catharticus*, *B. japonicus* and *Lolium multiflorum* are leafy annual fodder grasses and are widely scattered in vleis and on the edges of streams. They are of great value to stock especially in winter. *Melica racemosa* and *Ehrharta panicea* are frost resistant perennials and favour shady spots on the banks of the Modder River. *Helictotrichon turgidulum* is a robust erect grass which occurs frequently on the undisturbed borders of irrigated lands. It forms a close stand and is well-grazed by cattle during spring. Other adaptable perennials commonly found on the banks of watercourses are: *Sporobolus fimbriatus*, *Eragrostis plana*, *E. curvula*, *E. micrantha*, *E. nebulosa* and *Hordeum nodosum*. *Eragrostis hygrophila* and *E. porosa* are pioneer species growing on the dry beds of dams and pools. *Sporobolus iocladus* and *S. tenellus* are usually restricted to the edges of pans and dams.

Cyperaceae.

A total of 35 species was collected. The genus Cyperus is represented by the largest number of species and individuals. At certain spots, e.g. at Mockesdam, a number of species occurs together on a relatively small area. *C. marginatus and C. longus* are the most common along watercourses and streambeds. An unidentified *Cyperus* sp. (Mostert, No. 675), is a robust, stoloniferous sedge frequently found in the Modder River.

Scirpus fluitans, *S. dioecus* and *S.* sp. (Mostert, No. 382) are the most abundant species of the genus *Scirpus* and are generally found on the stream edges and in the bed of the Modder River. These species sometimes form dense patches. The genus Mariscus is poorly represented, *M. congestus* which occurs in streambeds being the most important species.

Eleocharis palustris, *Carex vulpina* and *C.* sp. (Mostert, No. 625) are fairly common in wet situations.

Juncaceae.

Juncus effusus and *J. exsertus* are the most abundant. The former occurs especially in the bed of the Modder River.

Liliaceae.

A few, e.g. *Albuca tenuifolia*, *Tulbaghia acutiloba* and *T. leucantha* were recorded from moist situations, i.e. in moist vleis and along edges of streams, but they also occur on raised portions of the streambanks and in the dry portions of the vleis. The bulbous plants *Thuranthos* sp. (Mostert, No. 683) an Urginea sp. (near *U. langii*) and *Ornithogalum prasinum* grow more or less gregariously on flooded situations in the Modder River valley. *Kniphofia ensiflora* var. *tuckii* is a robust species with rhizomes and with its yellowish-red flowers forms a beautiful sight along the edges of streams at Glen. It usually attains a height of four feet and is the only really hygrophilous Liliaceous species found in this area.

Amaryllidaceae.

This family is well represented in vleis and along watercourses. The white-flowered *Haemanthus amarylloides* is abundant and forms dense gregarious patches in wet vleis and on regularly flooded situations in the valley of the Modder River. (See photo 1). The bright red flowers of *Nerine laticoma* are very showy especially on the lower slopes of the valleys. *Crinum bulbispermum* has very large pink flowers 2 to 3 inches in diameter and is well represented in wet vleis and on the edges of streams and water furrows.

Iridaceae.

The poisonous yellow and blue flowered tulps (*Homeria pura* and *Moraea polystachya*) are widely scattered and common in vleis and wet places. They flower in spring and occur most abundantly on over-grazed sites. The tulps were much in evidence during the 1950 spring season, after the heavy winter and spring rains. They are seldom eaten and tulp-poisoning is therefore rare. *Gynandriris simulans* is blue-flowered and occasionally found in vleis.

(*c*) Dicotyledonae.

Polygonaceae.

Almost all the local representatives of the family occur in wet places, and sometimes in pure stands. The most abundant species are *Polygonum aviculare* and *P. plebium* which occur as weeds on moist lands and the sides of dams (see Figures 1 and 2). *P. lapathifolium* var. *glabrum* occurs in thick patches in the vleis, etc. Pure stands of the scrambler *P. convolvulus* and the erect *P. lapathifolium* have also been encountered in wet vleis but are not abundant. The robust *Rumex lanceolatus*, which attains a height of from 3 to 4 feet, comes in strongly on the lower river valley slopes and in the dry beds of spruits and may attain local dominance near dams.

Chenopodiaceae.

Chenopodium glaucum and *C. foetidum* are often found as pioneers on the outer edges of dams, the former occasionally being associated with *Polygonum aviculare.*

Amarantaceae.

Only two species of the family, *Amarantus muricatus* and *A. thunbergii*, show a high demand for moisture. These species have occasionally been found on the sides of dams associated with species of *Chenopodium* and *Polygonum.*

Ranunculaceae.

Ranunculus pubescens is more or less aquatic and occurs in moist depressions and along watercourses. This species occurs abundantly and is often associated with *Paspalum* spp. and *Polygonum* spp. *Thalictrum caffrum* is rare and restricted to moist shady spots on the banks of the Modder River valley at Glen.

Cruciferae.

Nasturtium elongatum, N. officinale, Rorippa caledonica and *R. fluviatile* are common perennial semi-aquatics favouring stream margins. On many situations they grow intermixed with the sedges and brighten up the dull stream edges with their flowers. *Raphanus raphanistrum* is a showy yellow-flowered annual occasionally found on irrigated lands.

Rosaceae.

Two species, *Potentilla supina* and *Alchemilla elongata*, are more or less hygrophilous. The first is found only on the sides of a dam at Glen where it forms a dense cover (see Figure 1). It reaches a height of six inches, has yellow flowers and is well grazed by sheep. *A. elongata* favours the edges of stagnant pools in the bed of the Modder River, but is not common.

Leguminosae.

Only a few species of this large family are hygrophilous. *Trigonella hamosa* is a prostrate perennial herb occasionally found as a pioneer on sandbanks and alluvial deposits in the bed of the Modder River. *Medicago denticulata* occurs abundantly on heavy soils in the valleys but is not restricted to such soils. The white-flowered legume *Melilotus albus* and the yellow-flowered robust species, *M. indicus* are restricted to water furrows and irrigated lands. These alien biennial legumes are grazed when young. *Trifolium africanum* is common on low-lying ground along the Modder River. It forms extensive mats, has showy dark reddish flowers in summer and is liked by stock. *T. dubium* (introduced) occurs occasionally on irrigated lands. The erect, robust *Sesbania mossambicensis* is a pioneer on the wet beds of dams and on the sides of furrows. *Sutherlandia microphylla* is an uncommon robust legume with large pinkish flowers. It reaches a height of five feet and occurs principally on the wet banks of the Modder River. Species of *Vicia* and also *Lessertia pauciflora* are quite common on irrigated lands and along water furrows. They grow during winter and are valuable winter grazing.

Oxalidaceae.

Oxalis latifolia usually favours moist shady spots and is occasionally found in dense patches along water furrows.

Onagraceae.

Five species of the genus *Oenothera* can be regarded as semi-aquatics usually confined to cool, moist situations. *Oenothera biennis*, with large showy yellow flowers, grows on the steep banks of the Modder River at Glen. The orange-flowered *O. nocturna* and *O. odorata* are widely distributed along roadsides, near streams, the edges of vleis, etc., and are often associated with *Ranunculus pubescens*. Another conspicuous orange-flowered *Oenothera* sp. is Mostert, No. 96, which is usually encountered on the steep banks of the Modder River. The pink-flowered *O. rosea* occurs abundantly in wet places throughout the area.

Umbelliferae.

A number of species is commonly found on wet places. *Bupleurum mundtii* is an erect well-rooted perennial herb with conspicuous yellow flowers. It occurs commonly on wet and dry spots on the steep banks of the Rhenosterspruit, near Glen. *Berula thunbergii* is a semi-aquatic in the beds of streams, where in shady protected situations it is often found in dense stands. *Apium leptophyllum* is common. *Pimpinella caffra* is found occasionally in vleis and in the beds of furrows.

Loganiaceae.

Gomphostigma virgata, a deeply rooted, white flowered perennial is common in the bed of the Modder River and other watercourses and blooms n summer.

Gentianaceae.

Except for *Sebaea compacta* all the representative species of the family are semi-aquatics. They are usually scattered and inconspicuous except for their bright yellow flowers. *S. pentandra* may be encountered as a pioneer on sandbanks in the Modder River.

Asclepiadaceae.

The family has a few important species commonly occurring in vleis and on streambanks, for example *Xysmalobium undulatum* which is a strong erect plant with large creamy flowers. *Schizoglossum eustegioides* and *Asclepias meyeriana* are small herbs with tuberous roots. They are common and bloom in early spring. Their flowers are small and creamish coloured. The erect, shrub-like *Asclepias fruticosa* is widely scattered and frequent in wet places and on old lands. It is drought resistant and not eaten by stock.

Convolvulaceae.

The parasite *Cuscuta campestris* (dodder) occurs frequently in the valleys of streams and in vleis on *Psoralea obtusifolia*, *Atriplex* spp., grasses, etc. *Falkia oblonga* occasionally forms dense mats in the bed of te Modder River, and is a valuable soil binder. *Seddera capensis* and *Convolvulus dregeanus* are two common species in this habitat. Both favour moist spots but are drought resistant and may also be found on the flats and higher slopes of the valleys. The latter is stoloniferous and often forms extensive mats in dry streambeds. It flowers prolifically and its pale pink flowers are quite showy. *C. arvensis* usually occurs as a weed in wet lands and on the edges of water furrows. As it is stoloniferous and deeply rooted, it is difficult to eradicate. *C. sagittatus* var. *latifolius* is also stoloniferous, occasionally forming extensive mats in vleis, and is a good soil protector.

Boraginaceae.

The robust *Anchusa capensis* is gregarious in the beds of a few spruits at Glen. It is perennial and remains green for the greater part of the winter.

Verbenaceae.

Four species occur. *Verbena officinalis*, *V. bonariensis* and *V. tenera* are perennial plants. The first species is a common weed in wet lands and the last two are frequently found on the banks of the Modder River. The last one is a mauve-flowered garden escape and occurs in patches. *Lippia canescens* is widely scattered and forms extensive mats on bare soil on the lower slopes of streambanks. Having a compact rhizomatous root system it is valuable in colonizing the steep banks and the islets in the Modder River. Its numerous light blue flowers are conspicuous during summer.

Labiatae.

Stachys hyssopoides is frequent on certain sites, e.g. on the lower slopes of streambanks. It is a valuable soil binder. The big blue-flowered *Salvia rugosa* and *S. runcinata* are fairly frequently found scattered in dry vleis and on the banks of streams.

Solanaceae.

Nicotiana glauca colonises the steep banks of the Modder River where it occurs in great numbers, but is frosted annually. It attains a height of 10 feet and has conspicuous yellow flowers. *Cestrum parqui* is another exotic shrub which grows gregariously in the beds of spruits and occasionally also on ridges.

Scrophulariaceae.

A few species of this large family are aquatic or sub-aquatic and although they may be common they never attain dominance. *Nemesia affinis*, an erect annual herb frequently grows in thick patches. *Limosella capensis* and *L. longiflora* are common, the former as a pioneer on the sand and alluvial banks of the Modder River. They form thick mats, approximately 1 to 3 inches high, and have attractive bluish flowers. The erect herbs *Mimulus gracilis* and *Veronica anagallis* are frequent in the beds of streams; the former has an extensive root system and often forms dense patches. *V. anagallis* which has bright blue flowers is particularly well represented in the Rhenosterspruit and favours shaded situations.

Plantaginaceae.

Two species of *Plantago* are widely scattered. *P. major* with its large tufts and well developed fibrous root system plays an important rôle in binding the streambanks against erosion. *P. lanceolata* is a weed on irrigated lands and in water furrows. These plants are frost resistant and are grazed by cattle.

Rubiaceae.

Only one species, *Galium garipense*, is common. It usually occurs gregariously and is an important pioneer on the sandbanks of the Modder River.

Campanulaceae.

The genera Wahlenbergia and Lobelia are well represented. *Wahlenbergia androsacea* is an erect blue-flowered herb approximately one foot high. Although it favours wet situations it may also occur in Themeda grassveld during seasons of copious winter and spring rains. After good spring rains in September, 1950, hundreds of morgen of open grassveld and cultivated fields at Glen, especially on sandy loam soil, were almost totally covered by it. It has not reappeared because of insufficient spring rains. *W. banksiana* favours the sides of furrows. *W. procumbens* which roots at the nodes is a short matted herb occasionally found on stream edges, and is an important pioneer on the margins of some dams. The light-blue-flowered *Mezleria depressa* and *Lobelia thermalis* are also common herbs, 1 to 2 inches high, forming dense mats; the former on edges of local dams and the latter on islets and alluvial banks in the Modder River.

Compositae.

A fair number of species occurs on irrigated lands and along streams. *Aster subulatus* and *Nidorella resedaefolia* are common; the former (blue-flowered) forms thick patches on lucerne lands, especially where the lucerne has died out. The latter (yellow-flowered) is a common pioneer on wet lands, in vleis, and on overgrazed alluvial soils in valleys. It is grazed when in flower during spring. The large genus Helichrysum has only two species, viz. *H. aureonitens* and *H. declinatum*. The latter is a prostrate to erect pioneer on the dry beds of dams and water furrows. *Lasiospermum bipinnatum* has large showy white-rayed flowers; it forms dense stands in the bed and on the lower banks of the Rhenosterspruit. *Cotula burchellii* and *Pentzia globifera* are two prostrate, aromatic, winter growing herbs frequently found as pioneers. The common soft-leaved annual winter growing herb *Cenia microglossa* occurs on heavy alluvial soils all along the main watercourses. During the wet spring of 1950 hundreds of morgen of heavy soil along the Modder River were practically covered by this bright yellow-flowered species. It has been relatively inconspicuous since. It is well grazed by stock and according to a local farmer taints milk.

The yellow-flowered *Senecio laevigatus* and *S. reptans* are widely distributed on irrigated lands, in water furrows and on edges of dams. *Platycarpha parviflora*, an acaulescent deep-rooted, stoloniferous herb forms dense patches in dry vleis and on the sides of irrigated lands. Many individuals of *Taraxacum officinale* are found on the banks of the Rhenosterspruit. *Venidium arctotoides* is a prostrate herb, rooting at the nodes, and forms dense patches on the sides of dams and furrows.

Weeds are represented by *Xanthium spinosum*, *Tagetes minuta*, *Flaveria contrayerba*, *Galingsoga parviflora*, *Cineraria lyrata*, *Berkheya onopordifolia*, *B. epitrachys*, *Tragopogon porrifolius*, *Sonchus oleraceus*, etc. Except for the lastnamed species, all these are more or less inedible.

CHAPTER 6.

THE VALLEY ACACIA BUSH COMMUNITY.

The Valley Acacia Bush, restricted to the valleys of the Modder River, spruits and numerous small flushes, is a well defined community and is sufficiently extensive to warrant a separate discussion. When viewed from the summit of a high hill the valleys bordering the watercourses ean be seen clearly by the presence of dense bush community. The width of the Modder River valley varies considerably, ranging from a few hundred yards to a few miles. The valleys of the spruits vary similarly. The width of the Acacia Bush community varies according to the width of the valley. At Glen and on the adjoining farm Glen Lyon this community is approximately 2 to 3 miles wide. In smaller valleys, it may be about a hundred yards or less in width and only in some of the smallest valleys is it absent.

In general the Valley Acacia Bush vegetation is mesophytic. Near the watercourses the trees are larger and form a closed community, becoming shorter and sparser towards the upper slopes, seldom exceeding a height of 12 feet. On the adjoining plains and lower slopes of the rises and koppies this community is replaced by grasses and karoo bushes, and where the trees do occur they are mostly solitary, thus forming a parkland-like vegetation. *Acacia karroo* and associated trees often, e.g. at Glen, form dense covers on the slopes of bults where surface or underground water is present.

The valleys usually have deep alluvial soils which may reach a depth of 20 feet. The underlying strata may consist of a heavy clay sub-soil or shale. These heavy, silty soils, require a large amount of water to sustain a mesophytic vegetation as part of the Acacia Bush community and if this is not available there is a tendency for xerophytes to become dominant in patches within the bush community.

Root observations on trees were made on a steep bank of a dry spruit at Glen (see photo 2) and on the steep eroded banks of the Modder River at Mockesdam. The spruit at Glen has a deeply eroded U-shaped watercourse 12 to 15 feet deep by 20 feet wide. It was found that the taproots of all the trees on the bank, i.e. *Acacia karroo*, *Ziziphus mucronata* and *Rhus lancea*, at a depth of approximately 1 to 3 feet below the bed level, turned towards the centre of the spruit-bed. At this depth the diameter of the tap-root of *A. karroo* had decreased from approximately four inches at the soil surface to approximately 1 to 2 inches. It was found that the trees are not only deep rooted but make good use of the water drained to and gathered in the watercourses as a result of which the trees and shrubs are taller and more robust than those further from the watercourses.

As has been indicated in Chapter 5 the vegetation of the valleys has been much modified by human influences resulting in erosion and bush encroachment.

The typical Valley *Acacia karroo* community is relatively simple and has an interesting undergrowth. A characteristic feature is the dominance of *A. karroo*. Other tree species are intermingled but never become dominant. The Valley Acacia bush community will be discussed under the following headings:—

(1) Valley Bushes and Shrubs.

(2) Undergrowth.

(3) Heliophilous vegetation on open situations.

1. VALLEY BUSHES AND SHRUBS.

(*a*) Acacia karroo.

A. karroo is a well known and widely spread South African tree. Bews (1925) maintained that " the presence of Acacias in many cases is due to lime in the soil " . . . Potts and Tidmarsh (1937) stated, however, that communities of *A. karroo* have also been found on soils showing an acid reaction. According to Story (1952), *A. karroo* occurs on acid soils with pH values of approximately 5·5. Story, who gave an extensive review of of our knowledge of *A. karroo*, came to the conclusion that this tree is undiscrimating as to soils and that it is probably not much affected by the pH of the soil. The soils in the valleys of the Bloemfontein–Brandfort area appear to be fairly rich in lime. Where *A. karroo* occurs in the latter area the pH of the soils varies in general between 7 and 8.

A. karroo varies in size and may attain a height of 10 to 20 feet with one or more boles and widely spread branches. From the ground surface to approximately breast height the main stem of well developed *A. karroo* trees is fairly straight. From this height it usually branches freely, attaining a fan-shaped profile. When the stem of a tree is chopped off near ground level it usually coppices freely. Younger trees are more or less shrubby, especially when growing on dry situations.

After good summer rains the bright yellow flowers of the Acacia trees give the whole valley a yellow appearance (generally in December). The first leaves are produced in October and are usually shed about May or June. Its green and dead leaves and also the pods are eaten by stock, which fact is appreciated by farmers. M. C. F. du Plessis of the Glen College of Agriculture analysed the green leaves. In June, 1949, they had a " protein " (N $\times$ 6·25) content of 11·6 per cent on an oven-dried basis.

As the Acacia trees are deciduous the ground underneath them yearly receives some organic material, which may accumulate up to one inch or more in depth. It occurs in different stages of decomposition and a rich earthworm population is often encountered in these humus soils.

From casual observations it seems that *Acacia karroo* is encroaching in the valleys, especially on disturbed and overgrazed situations, but the condition is not serious as yet. Seed of *A. karroo* does not germinate every season and little seedling establishment was seen between 1951 and 1955. Trees attaining a height of three feet are normally about five years old and are common in the local valleys whereas young trees up to about six inches high are usually scarce. The ideal vegetation in the valleys, from a grazing point of view, would undoubtedly be a park land, i.e. a good grass cover between scattered trees.

(*b*) Characteristic Associated Trees and Shrubs.

The associated trees and shrubs are found along the streams and on drier spots in the valleys where they show a marked degree of drought resistance. The most common associated tree is *Ziziphus mucronata* which occurs to a lesser extent in Randjieveld and Grassveld and is widely distributed in South Africa. During very cold winters it may be deciduous but often remains green throughout the year. Its leaves and berries are eaten by stock and according to local farmers the value of these trees, for fodder purposes, cannot be overrated. In view of its palatability and drought resistance it is propagated on a large scale at the Glen College of Agriculture. Seed germination tests showed that they do not germinate before the endocarp is removed or softened. Softening was achieved by allowing the drupes to soak in a concentrated lime-water solution for a few days. Seventy-five per cent germination was obtained from seed mechanically separated. After the seedlings had reached a height of about six inches, after approximately one season, they were transplanted into the veld and they mostly required watering in the first year after transplanting. Very few cases of natural regeneration were observed in this area. For proper utilisation it is necessary to remove the lower branches and encourage a canopy to afford shade for stock.

M. C. F. du Plessis analysed the dropped green-coloured leaves of this tree in June, 1949. They had a "protein" ($N \times 6{\cdot}25$) content of 12·35 per cent on an oven dried basis. The berries of *Z. mucronata* are much liked and are distributed by birds.

The next most widely spread tree in this community is the unarmed *Rhus pyroides*. It is almost completely restricted to stream banks in Valley Acacia Bush community. It is a much branched leafy tree up to 12 to 15 feet high, drought resistant, well rooted and forming dense rounded clumps in which little undergrowth is possible. It is valuable for shade in summer and for shelter in winter.

The evergreen tree *Rhus lancea* occurs in much smaller numbers than *R. pyroides*. It usually has a single bole and reaches a height of 15 feet. It favours streambanks and its leaves are browsed by stock during droughts.

Royena lycioides and a variety of *R. hirsuta* are flexible leafy shrubs occasionally found on the banks of watercourses. They rarely occur in other communities. Both species grow to a height of 6 to 10 feet forming dense clumps. The former favours shady spots and occurs in undergrowth. The flowers are rich in nectar and are much visited by bees and other insects. Both shrubs are unpalatable to stock.

The beautiful trees *Buddleja salicifolia* and *Celtis africana* may be encountered in the valleys but are more characteristic of the slopes of randjies (see Chapter 7). *Celtis africana* attains a height of 12 feet or more and is widely used as an ornamental tree.

The species of *Lycium* are common in Valley Acacia Bush community but are not restricted to it. They thrive in the shade of *Acacia karroo* and *Ziziphus mucronata* but usually occur as dense clumps in open situations between the trees where they are encroaching. *L. echinatum* is the most common. It has spinescent branchlets and forms very dense clumps approximately eight feet high, commonly on the banks of rivers.

Although worthless as a fodder species it is of some value as the first shrub to colonize steep bare soil. *L. hirsutum* is also a robust shrub occurring in the valleys. It spreads by lateral branches rooting where they touch the ground. This inedible species is also encroaching on lime-soil bults where clumps with a circumference of 38 yards have been found (see photo 3). *L.* sp. cf. *L. oxycladum* is a stoloniferous dwarf shrub 2 to 3 feet high frequent on open eroded situations in the valleys. All these species form such dense clumps that little undergrowth is possible.

Of the Monocotyledonae the genus Asparagus (*Liliaceae*) is the only shrubby representative occurring on river banks and in the valleys. *A. rivalis* and *A. laricinus* are the two most common species. They are white-flowered and form thick spiny clumps, approximately six feet high, near watercourses. They develop into climbers or ramblers and may completely cover small trees. They are inedible to stock.

(*c*) Climbing Species.

The climbers *Clematis brachiata*, *Antizoma harveyana*, *Cynanchum virens* are common while *Riocreuxia polyantha* is rather rare. *Clematis brachiata* has numerous showy white flowers and may cover the top of its supporting shrubs. *Cynanchum virens* attains heights up to 15 feet and with the associated trees and shrubs it forms a dense canopy on the banks of the Modder River. The common scandent shrub *Antizoma harveyana* may also ramble on the tops of small trees and shrubs.

Another climber, *Kedrostis africana*, and a large scandent herb *Galium horridum* may occasionally be found in the Bush community. These species are not restricted to the valleys and are also found at the foot of hills or on flats where *Acacia karroo* occurs.

The stem parasite *Viscum rotundifolium* is often found on various host trees, e.g. *Acacia karroo*, *Olea africana* and *Ziziphus mucronata*, growing in the valleys and on the hills, ridges and koppies. It is, however, most abundant on the trees occurring on the randjies.

2. THE UNDERGROWTH OF THE TREES AND SHRUBS.

It was stated by Bayer (1933), that the effect of the pioneer trees, e.g. *Acacia karroo*, is " to shade the soil, decrease the evaporation rate, and generally to create conditions which favour the development of more hygrophilous types."

The undergrowth of the trees and shrubs consists of two different groups of plants, i.e. shade-loving species and heliophilous plants. Although the heliophilous grasses and forbs forming part of the undergrowth are not actually shade-demanding they are more abundant under the trees in places where they find protection against overgrazing.

The sciophilous species are restricted to the shade of the trees and shrubs and some of them are confined to the Valley Acacia Bush community.

On the streambanks the canopy is usually very dense. As a result the ground-vegetation is poorly developed and consists of few species. Where the tree community is less dense, the ground underneath the trees is more closely covered by grasses and other plants.

(*a*) The Sciophilous Species.

(1) *Grasses.*

Only four species, i.e. *Ehrharta panicea* (not very abundant), *Melica decumbens*, *M. racemosa* and *Bromus catharticus* are typical sciophilous species underneath the trees in the Valley Bush community. The last three species are well represented and quite common in the valleys. *E. panicea* and the Melicas are restricted to this community, whereas *B. catharticus* is present in several communities, viz. along water furrows, in gardens, etc.

All the abovenamed plants seldom occur in open situations. They are all evergreen and grow most prolifically and are most leafy in spring and autumn. During seasons of high autumn, winter and spring rains they flourish best, e.g. in 1950, when heavy winter and spring rains fell, dense stands were conspicuous beneath the trees.

Two other sciophilous grasses, green in winter, are *Tetrachne dregei* and *Agrostis lachnantha*. The former is very rare in this area and the latter most common along water furrows, edges of dams, etc. The winter growing pioneer *Poa annua* also occurs in the shade of trees in the valleys but it is not very abundant and is of minor grazing importance.

As these grasses are succulent in winter and spring the valley camps are the best for winter-spring grazing and should receive regular rest periods in summer.

(2) *Other Species.*

Dipcadi viride and *Ornithogalum* sp. cf. *O. graminifolium* are the two Liliacious species most frequently found in this community. They are more or less sciophilous plants and grow best underneath the trees where decomposed organic material is present. The white-flowered succulent *Delosperma herbeum* is also a characteristic sciophilous species of this community. It is particularly well represented in the valley of the Modder River at Glen.

Lepidium trifurcum and *Sisymbrium capense* are erect, more or less sciophilous herbs frequently found in the shade of the trees and shrubs in the valleys only. They may occur on situations with very dense shade. *S. capense* is one foot high and has beautiful yellow flowers. The small sciophilous succulent *Crassula* sp. about nine inches tall, cf. *C. turrita*, is confined to the valleys, being evident in that of the Modder River, in the shade of shrubs and bushes.

It is interesting to note that not a single species of the large families *Leguminosae* and *Convolvulaceae* was found in this shade-loving community. *Teucrium capense* is an unpalatable undershrub frequently spread in the shade of *Acacia karroo* but it is not restricted to the valleys. The erect bluish-flowered shrublet *Walafrida geniculata* occurs often in the shade of the trees in the valleys. It occurs, however, also on the slopes of randjies where it grows as a heliophilous species.

Of the *Compositae* the most common sciophilous species found in the valleys are *Conyza ivaefolia*, *Pulicaria capensis* and *Artemisia afra*. The beautiful blue-flowered *Garuleum pinnatifidum* is characteristic of the undergrowth of the valleys, but also occurs on the southern slopes of the koppies.

(*b*) Heliophilous Species Underneath the Trees and Shrubs.

Two heliophilous grasses, viz. *Panicum coloratum* and *P. stapfianum* which are characteristic of the Valley–Vlei Grassveld community are also frequent underneath the trees in the valleys of the larger watercourses. They are summer-growing grasses, the latter species being the most abundant. These grasses are leafy and palatable and the valley trees and shrubs merely afford protection to them with the result that they are not easily trampled out and stay green much longer during winter than the tufts on open places. The spaces between their tufts are either bare or are occupied by ruderals or sciophilous winter-growing grasses.

Panicum maximum, a broad-leaved summer-growing grass is occasional on wet shady spots. It is dominant in the undergrowth of the trees on the banks of the Modder River at Mazelspoort. This grass is, however, not restricted to the valleys but occurs also in shady spots on the slopes of randjies (see Chapter 7). *Digitaria eriantha* is a common species in Themeda grassveld but also occurs occasionally in the shade of trees and shrubs in the valleys.

This grass undergrowth is not of great importance for grazing during summer because the animals do not graze under the dense trees when the veld is green on the open situations. In winter these grasses are, however, eagerly sought and of great grazing value. As these heliophilous grass species seed in summer, winter grazing does not reduce their cover.

(*c*) Ruderal Herbs underneath the Trees and Shrubs.

In addition to the species enumerated in the two preceding sections, a number of ruderal herbs are found underneath the trees and shrubs, especially on bare spots. As these ruderals are pioneers on disturbed places occurring in several communities, e.g. Grassveld, Randjie-veld, etc., they cannot be regarded as characteristic species for the Valley Acacia Bush community.

Lepidium ruderale, *Achyranthes aspera* and *Cineraria lyrata* are erect, more or less sciophilous summer growing herbs frequent in the shade of the trees. The winter growing pioneer *Chenopodium album* is common on bare soil under the trees as well as on open situations. *Atriplex erosa* and the prostrate shrublet *A. semibaccata* are two edible species equally at home on shady and open spots. The latter is an exotic species which has become well acclimatised and is widely scattered in the drier parts of this country.

Ruderal grasses like *Setaria verticillata* are also common underneath the trees.

These pioneers are of little or no grazing value yet they are of some importance in colonizing bare soils underneath the trees and shrubs.

3. HELIOPHILOUS SPECIES ON OPEN SITUATIONS.

On the outer flanks of the Acacia karroo community, on the banks of the watercourses and also on the higher slopes of the valleys, the bush community is more open. The open spots vary in size from a few square yards to a few morgen and are covered by typical heliophilous communities which are either mesophytic (Valley Grassveld) or xerophytic (locally called

Gannaveld). In the valleys where part of the rain accumulates in the form of run-off water, grasses are characteristic and on protected spots become luxuriant. Typical Gannaveld species are well represented and form a characteristic vegetation on the open places between the Acacia Bush and Valley Grassveld communities (see photo 4).

A diagram showing the distribution of the Gannaveld, Bushveld and Valley Grassveld communities, in a part of the valley of the Modder River at Glen, is presented in Figure 4.

This transect was made along the western boundary of the farm of the Glen College of Agriculture and is nearly one mile long. The greatest part of the valley shown in Figure 4 is covered by the Valley Acacia Bush and the Gannaveld communities. In the southern part of the transect the Valley Grassveld community occurs as well as a mixture of the Valley Grassveld and Gannaveld communities.

(*a*) Gannaveld.

The Gannaveld occurs most abundantly in the valley of the Modder River but is also well represented in the valleys of the larger spruits. Although one would expect mesophytic grasses and forbs to thrive on the heavy soils along the watercourses the fact is that on many situations these soils receive little or no run-off water and require a high rainfall or floods to sustain mesophytes. On places where a high run-off occurs and little water penetrates into the soil, the habitat becomes too dry for the grasses, and typical drought resistant plants which resemble those of the Karroo are encountered. Under the rather low rainfall (20 to 21 inches per annum) the heavy silty soils apparently cannot carry much more than xerophytes, with occasional annual pioneers which appear during seasons of good rains and die off in dry periods. The perennial karroid plants (gannas, etc.) are, however, deeply rooted and can resist droughts when the heavy soils crack and dry out. The ruderals usually germinate soon after heavy rains and quickly complete their life cycle.

(1) *Botanical Surveys of Typical Gannaveld.*

To gain information as to which species characteristically constitute the Gannaveld community in the valleys of the larger watercourses, four botanical surveys were made. These surveys were made with the Wheel Point apparatus and the results are presented in Tables 7 and 8.

FIGURE 4.

LINE TRANSECT SHOWING THE DISTRIBUTION OF THE COMMUNITIES IN A PART OF THE VALLEY OF THE MODDERRIVER AT GLEN, 18-1-1954.

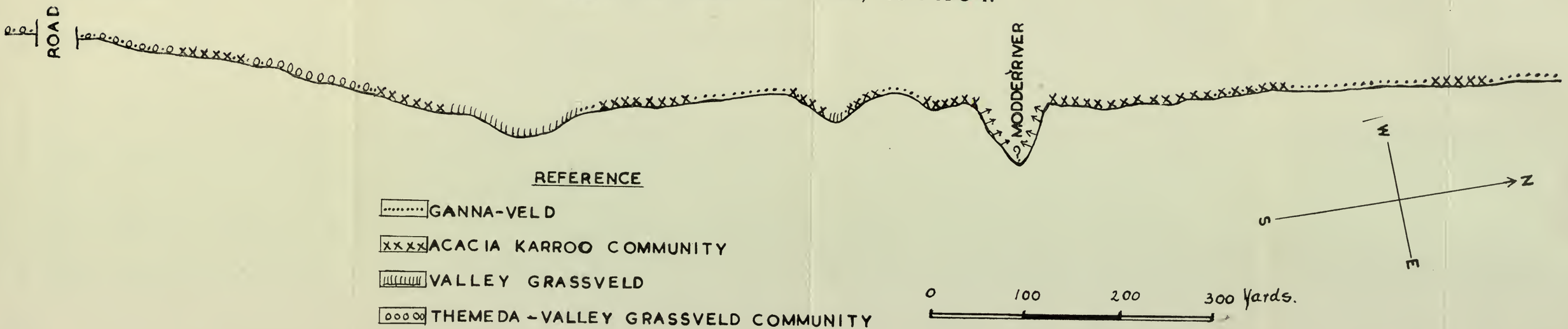


TABLE 7.—*Botanical Surveys of Typical Gannaveld occurring in the Valley of the Modder River. Species are classified according to their Degree of Presence. Percentage Basal Cover and Percentage of Vegetation. Wheel Point Method, Lines Six Yards apart and Points 4·7 Feet apart within Lines:* 1,000 *Points per Plot.* (2,000 *Points on Plot No.* F. 16, *Lines Eight Yards apart and Points* 3·1 *Yards within Lines*).

Camp No.	Degree of Presence out of 4.	F. 16.		A. 1A.		A. 4.		Bishop's Glen.		Height.
Size of Area Surveyed.		Five Morgen.		One Morgen.		One Morgen.		One Morgen.		
Date of Survey.		22nd April, 1953.		23rd September, 1953.		24th September, 1953.		24th September, 1953.		
Species.		Percentage Basal Cover.	Percentage of T. Veg.	Percentage Basal Cover.	Percentage of T. Veg.	Percentage Basal Cover.	Percentage of T. Veg.	Percentage Basal Cover.	Percentage of T. Veg.	
Salsola glabrescens.....	4	1·9	15·0	3·1	23·7	2·3	20·7	1·5	14·0	C
Aster muricatus.....	4	1·8	14·2	1·8	13·7	0·3	2·7	2·8	26·2	B
*Chloris virgata**.....	4	1·3	10·2	1·4	10·7	0·9	8·1	0·9	8·4	B
Eragrostis obtusa.....	4	0·4	3·1	0·6	4·6	0·3	2·7	1·4	13·1	B
*Cyperus usitatus**.....	4	1·15	9·1	0·3	2·2	0·2	1·8	0·2	1·9	A
*Tragus racemosus**.....	3	1·7	13·0	1·1	8·4	—	—	0·1	0·9	A
Cynodon hirsutus.....	3	0·55	4·3	0·3	2·3	—	—	0·5	4·7	A
Eragrostis curvula.....	3	—	—	0·3	2·3	0·4	3·6	0·3	2·8	C
Lycium oxycladum.....	3	0·1	0·8	—	—	0·1	0·9	0·1	0·9	C
Mestoklema tuberosum.....	2	0·9	7·2	2·2	16·8	—	—	—	—	C
*Hypertelis verrucosa**.....	2	0·8	6·3	0·4	3·0	—	—	—	—	A
Sporobolus ludwigii.....	2	0·2	1·6	0·1	0·7	—	—	—	—	B
Tragus koelerioides.....	2	0·15	1·2	—	—	—	—	1·0	9·3	A
Nestlera conferta.....	2	0·15	1·2	—	—	—	—	0·7	6·5	B
Crassula turrita.....	2	0·1	0·8	0·1	0·7	—	—	—	—	A
Medicago denticulata†.....	2	—	—	0·4	3·1	2·1	18·9	—	—	A
Delosperma mahoni.....	2	—	—	0·2	1·5	—	—	0·7	6·5	A
Choritaenia capensis†.....	2	—	—	0·5	3·8	0·1	0·9	—	—	A

*Summer growing annuals and ruderals. †Winter growing annuals and ruderals. A = Plants 1 to 3 in. high; B = Four to 12 in. high; C = More than 12 in. high. Value of T = 1·65. (Total cover of A. 1A and Bishop's Glen compared.)

TABLE 7.—*Botanical Surveys of Typical Gannaveld occurring in the Valley of the Modder River. Species are classified according to their Degree of Presence. Percentage Basal Cover and Percentage of Vegetation. Wheel Point Method, Lines Six Yards apart and Points 4·7 Feet apart within Lines:* 1,000 *Points per Plot.* (2,000 *Points on Plot No.* F. 16, *Lines Eight Yards apart and Points 3·1 Yards within Lines*) (contd.).

Camp No.	Degree of Presence out of 4.	F. 16.		A. 1A.		A. 4.		Bishop's Glen.		Height.
Size of Area Surveyed.		Five Morgen.		One Morgen.		One Morgen.		One Morgen.		
Date of Survey.		22nd April, 1953.		23rd September, 1953.		24th September, 1953.		24th September, 1953.		
Species.		Percentage Basal Cover.	Percentage of T. Veg.	Percentage Basal Cover.	Percentage of T. Veg.	Percentage Basal Cover.	Percentage of T. Veg.	Percentage Basal Cover.	Percentage of T. Veg.	
Gynandriris simulans†.....	2	—	—	0·1	0·7	0·1	0·9	—	—	B
*Eriospermum corymbosum**..	1	0·3	2·4	—	—	—	—	—	—	A
*Ornithogallum prasinum**....	1	0·25	2·0	—	—	—	—	—	—	B
Aristida congesta.....	1	0·25	2·0	—	—	—	—	—	—	B
Blepharis integrifolia.....	1	0·15	1·2	—	—	—	—	—	—	A
Dimorphotheca zeyheri.....	1	0·15	1·2	—	—	—	—	—	—	B
Cenia microglossa†.....	1	—	—	—	—	2·2	19·8	—	—	A
Eragrostis bicolor.....	1	—	—	—	—	1·2	10·8	—	—	B
*Brachiaria eruciformis**.....	1	—	—	—	—	0·6	5·4	—	—	B
Themeda triandra.....	1	—	—	—	—	—	—	0·5	4·7	C
Nemesia affinis†.....	1	—	—	0·2	1·5	—	—	—	—	A
Setaria nigrirostris.....	1	—	—	—	—	0·3	2·7	—	—	C
Species constituting less than 1 per cent of total veg....	—	0·4	3·1	—	—	—	—	—	—	—
TOTAL.....		12·7	99·9	13·1	99·7	11·1	99·9	10·7	99·9	—
Number of species.....		25		17		14		13		

*Summer growing annuals and ruderals. †Winter growing annuals and ruderals. A = Plants 1 to 3 in. high; B = Four to 12 in. high; C = More than 12 in. high. Value of T = 1·65. (Total cover of A. 1A and Bishop's Glen compared.)

TABLE 8.—*Botanical Composition of Gannaveld. Species are arranged in Groups more or less according to their Perenniality.*
(Summary of Table 7).

Groups.	Percentage of Total Vegetation (basal cover).			
	Camp F. 16.	Camp A. 1A.	Camp A. 4.	Bishop's Glen.
1. Annual plants (including ruderals).....	47·6	33·4	55·8	11·2
2. Perennial grasses.....	11·0	9·9	19·8	34·6
3. Shrubs and perennial herbs.....	41·3	56·4	24·3	54·1
TOTAL.....	99·9	99·7	99·9	99·9

(i) *Camp* F. 16.

A survey of five morgen of Gannaveld which constitutes part of a 33 morgen *Acacia karroo* bush camp, No. F. 16, at the Glen College of Agriculture, was made on 22nd April, 1953 (see also map No. 1). Approximately half of this camp is covered by *A. karroo* with large open spaces between the bush clumps which are occupied by Gannaveld species. The soil is heavy black clay and has a slight inclination towards the Modder River. Camp F. 16 was grazed for many years, especially by horses. Through the last six years one adult horse was carried on nine morgen of veld but the animals regularly received additional feeding.

(ii) *Camp* A. 1A.

One morgen of typical Gannaveld which constitutes a part of camp A. 1A, at the Glen College of Agriculture, was surveyed on 23rd September, 1953. The area is 200 yards from the Modder River (see map No. 1). The soil is heavy clay and has a slight inclination towards the river. On all sides of this Ganna community Acacia thickets occur. Camp A. 1A was grazed only during periods of scarcity. It was well rested for at least 20 years or longer.

(iii) *Camp* A. 4.

One morgen of Gannaveld occurring in camp A. 4 at the Glen College of Agriculture was surveyed on 24th September, 1953 (see map No. 1). The soil is heavy black clay having a very slight inclination towards the Modder River. The area lies 500 yards from the Modder River and is bounded on all sides by Gannaveld. This camp was grazed by cattle and the stocking rate is given in Chapter 8, section 1 (*a*).

(iv) *Bishop's Glen.*

One morgen of Gannaveld occurring in a camp on the farm Bishop's Glen was also surveyed on 24th September, 1953. This camp adjoins the farm of the Glen College of Agriculture and lies between the Rhenosterspruit and the Modder River. The ground has an almost imperceptible slope and is a heavy black clay. The area surveyed is bounded on all sides by *Acacia karroo* thickets. This camp was rested in summer and usually grazed in winter.

(v) *Comparison of results.*

In Table 7 the plant species are classified principally according to their degree of presence. The approximate height of the plants is also given. The main aim with this table is to give a picture of the botanical composition of Gannaveld occurring in the valley of the Modder River. From Tables 7 and 8 the following conclusions can be drawn:—

(1) The Gannaveld communities investigated have a total basal cover ranging from 10·7 to 13·1 per cent, statistically the differences are not significant. Shrubs, shrublets and perennial herbs are well represented. Except in the plot at Bishop's Glen the annual plants are much better represented than the perennial grasses which constitute a small percentage (9·9 to 34·6) of the total vegetation. The percentage total basal cover of this community (10·7 to 13·1) is much lower than that of Valley Grassveld (16·4 to 27·1).

(2) The two most important constituents of the Ganna community are the two bushes *Salsola glabrescens* and *Aster muricatus* which are constantly present. According to the figures for basal cover *S. glabrescens* is the dominant in two out of the four plots investigated. In plot F. 16 it is co-dominant with *A. muricatus* and *Tragus racemosus*. On Bishop's Glen *A. muricatus* dominate with *S. glabrescens* and *Eragrostis obtusa* as sub-dominants. *S. glabrescens* is, however, a robust dense bush and is much more conspicuous than the small *A. muricatus* and the grasses and annuals. It usually appears to be the dominant species in the Gannaveld community. Species with a high degree of presence which occur in all the four plots, though in varying percentages, are: *Chloris virgata*, *Eragrostis obtusa* and *Cyperus usitatus*.

The most characteristic species of this Ganna community, are (summary of Table 7):—

Species.	*Degree of Presence.*	*Degree of Abundance.* Per Cent.
Salsola glabrescens.....	4	14–23·7
Mestoklema tuberosum (restricted to Gannaveld).....	2	0–7·2–16·8
Hypertelis verrucosa.....	2	0–3–6·3
Crassula sp. cf. *C. turrita* (restricted to Gannaveld).....	2	0–0·7–0·8

(3) The ruderal *Tragus racemosus* and the pioneer *Cynodon hirsutus* occur in three of the four stands examined and are frequently present in this community. The perennial grass *Eragrostis curvula* is often present but never constituted more than 3·6 per cent of the total vegetation investigated. The encroaching shrub *Lycium oxycladum* also occurs frequently but always in smaller percentages than *Eragrostis curvula.*

(4) Ten species listed in Table 7 were found in two out of the four stands and are often present in the Ganna community. Of the two succulents *Mestoklema tuberosum* and *Delosperma mahoni*,

the first-named species is the more important. It occupies as much as 16·8 per cent of the total plant cover on the surveyed part of the camp A. 1A. The perennial pioneer grasses *Sporobolus ludwigii* and *Tragus koelerioides* are often present and usually occur on bare places.

(5) The 11 species at the end of Table 7 were in only one of the four stands examined and are unimportant. They are rarely associated with the Gannaveld community. Although *Cenia microglossa* and *Eragrostis bicolor* may occur in great numbers (e.g. in camp A. 4 where each of them constitutes more than 10 per cent of the total vegetation) they are not restricted to the Ganna community. The occurrence of the first-named species is strongly influenced by rainfall and seasons.

(6) *Crassula* sp. cf. *C. turrita* is rare and restricted to this community and occurs only in the shade of bushes and shrubs.

(7) As stated under (1) perennial grasses in general make up little of the total basal cover of the Gannaveld. *Themeda triandra* was found only in the plot at Bishop's Glen, where it constitutes 4·7 per cent of the total vegetation. *Eragrostis obtusa* is better represented in this than in other plots examined. *Tragus koelerioides* was found in the five morgen plot F. 16, but was commoner in the sample taken at Bishop's Glen (1·1 and 13·1 per cent respectively). It seems therefore most probable that the sample at Bishop's Glen is not such typical Gannaveld as the other sample studied but represents rather a transition stage between Gannaveld and Valley grassveld.

(8) As this community contains many annuals it is evident that its recorded botanical composition varies with the season in which the surveys are made. Shrubs and perennial grasses are, however, identifiable more or less throughout the year and normally their absolute numbers would not be modified much by seasonal changes. The seasonal aspect is dependent principally on the presence of different annuals, ruderals and geophytes. When surveys are made in winter and spring the following winter growing species will most likely be found: *Medicago denticulata*, *Choritaenia capensis*, *Cenia microglossa*, *Nemesia affinis* and *Gynandriris simulans* (geophyte). In surveys made during summer and autumn *Chloris virgata*, *Tragus racemosus*, *Hypertelis verrucosa*, *Cyperus usitatus*, *Brachiaria eruciformis* and different geophytes according to their flowering time (cf. next section) will probably be present.

The annuals and ruderals occupy the open spaces between the bushes, shrublets and perennial grasses. The ruderal grasses grow in summer (October to March) but disappear in winter (May to June) to be followed by winter growing annuals. Winter growing annuals are usually most conspicuous when in flower, viz. in spring (September to October). This is especially true for the bright yellow-flowered *Cenia microglossa*.

(9) The poisonous conspicuously flowered *Gynandriris simulans* and *Dimorphotheca zeyheri* are often found in this community. As animals seldom seem to eat these plants, poisoning is rare.

(2) *Notes on Some of the Species Occurring in the Gannaveld Community.*

Gannaveld derives its name from two species of *Salsola*, i.e. *Salsola glabrescens* and *S. nigrescens* locally called " Ganna." On protected spots *Salsola glabrescens* may be very luxuriant attaining a height of three feet. *S. nigrescens* is sometimes also found in the valleys on heavy soils. It was not recorded in the four plots of which a detailed survey was made but is occasionally associated with *S. glabrescens*. In general *S. nigrescens* is scattered, usually forming patches and occurring in much smaller numbers than *S. glabrescens*. These species of Salsola are also found in Valley-Vlei Grassveld where they may be associated with perennial grasses but never attain dominance. The gannas are among the best fodder bushes in this area (Henrici 1935), and are valuable for winter and spring grazing.

The perennial succulent *Mestoklema tuberosum* is one of the most characteristic species found in the Gannaveld. It is a bushy much branched shrub, 1 to 2 feet high and has a thick stem and a thick, branched tap root. It is drought resistant, spineless and has numerous small orange-coloured flowers. This species is only occasionally browsed by cattle and horses.

The pioneer biennial succulent *Delosperma mahoni* is often found on bare spots in the Gannaveld. It is approximately four inches high and has large showy dark pinkish flowers. This species is especially conspicuous during years with good winter and spring rains. After the heavy rains received in the early spring of 1950 hundreds of acres were practically covered in November by this floriferous succulent. Although it favours the heavy soils in the valleys it occurs also on lighter sandy soils on the bults. Its leaves are usually eaten during droughts.

The unpalatable *Galenia namaensis* is often found on open situations in the valley of the Modder River. It has numerous small, unconspicuous, whitish flowers.

The following pioneer species were not recorded in the surveys and are occasionally associated with the Gannaveld community: *Galenia pubescens*, *Medicago laciniata*, *Salsola kali*, *Atriplex semibaccata*, *A. erosa* and *Delosperma herbeum*. Except for the last species, which prefers shady situations, all these pioneers usually occur on bare soil between the bushes and shrubs.

The stem succulent *Euphorbia clavarioides* forms dense cushions approximately 1 to 2 inches above the soil surface. These cushions may reach a diameter of nine inches. It grows in open situations between the shrubs and trees, is restricted to the valleys and is more frequent in Gannaveld than in Valley–Grassveld. It has small yellow flowers and is nibbled by sheep during droughts.

Seasonal Aspects.

In addition to the species mentioned in Table 7 a few spring and summer growing Liliaceous geophytes are often found in the Gannaveld community, especially in the valley of the Modder River. In general they are visible only after heavy spring or summer rain. The following are the most common: The yellow-flowered *Bulbine asphodeloides* and *B. caespitosa* usually flower from November to January. Both species may also be found in Themeda grassveld. *Tulbaghia acutiloba* and *T. leucantha* are orange-flowered geophytes and are usually in bloom during mid-summer.

They also occur on regularly flooded situations in the valleys as well as in the Valley–Vlei grassveld communities. The white flowered *Urginea* sp. (Mostert, No. 196) occasionally appears in great numbers on heavily grazed spots between the Gannas and in open Valley grassveld. It usually flowers between January and March. *Albuca tenuifolia* has beautiful yellow flowers and occurs here and there in the Gannaveld as well as in wet places in the valleys. *Ammocharis coranica* is often found in the valleys and is usually associated with grasses or with *Salsola glabrescens* and *Aster muricatus* (see photo 5). It flowers during February and March and has broad flat leaves spreading on the ground.

(*b*) Valley Grassveld.

Often all three of the valley communities, i.e. Valley Acacia Bush, Valley Grassveld and the Gannaveld can be found on a small area less than one morgen in extent. As has been indicated previously the Valley Grassveld is restricted to occasionally flooded places and situations where run-off water collects. This grass community also varies in size from a few square yards to a few morgen. A detailed account is given in Chapter 8.

CHAPTER 7.

RANDJIE-VELD.

(The Vegetation of the Hills, Ridges and Koppies).

There are no mountains, and the hills and ridges usually rise only a few hundred feet above the level of the plains. They constitute 10 to 20 per cent of the area studied. Trees and shrubs form the characteristic vegetation of the randjies.

As has been indicated in Chapter 1 the randjies are concentrated north of Bloemfontein towards Glen and Mazelspoort. North of Karree and to the western and eastern parts of this area there are only a few hills and koppies separated by miles of level plains. These randjies consist chiefly of dolerite, with a few small ridges or outcrops of sandstone, principally as structural terraces. The soil of the randjies is usually shallow, especially on the northern slopes, where it is also very coarse and stony. The southern slopes, especially of the larger hills, have deeper soils and large irregular doleritic boulders scattered here and there.

The slopes of the hills and koppies are moderate and krantzes are uncommon. As the hills are so low (100 to 400 feet) the difference in altitude may be of minor importance as a general factor in plant distribution.

The influence of the climatic factors on plant growth is modified to a large extent by the angle and direction of slope of the hills, ridges and koppies. The amount of insolation is greatest on the northern side. Bews (1925), and Potts and Tidmarsh (1937), showed that slopes facing north have a much more xerophytic type of vegetation than the opposite sides.

Potts and Tidmarsh (1937) concluded that it is the soil type which is responsible for the occurrence of bush and that the bush is commonly found on the deep soils facing south.

Generally the bushes occur on the southern slopes of the randjies. Dense communities are, however, also encountered in the kloofs and on the sides of dongas amongst the hills facing any direction—often west or north. Typical examples of kloofs facing north which are thickly covered by trees and shrubs can be seen on the farm Glen Lyon near Glen. It seems that the deeper soils and higher humidity are responsible for the bush development. Where a deep soil is found on the drier and hotter northern slopes the trees are as well developed as on the cooler southern slopes.

It has further been observed that on small and broadly rounded koppies and low ridges (i.e. at Glen) there is very little difference between the vegetation on the southern and on the northern slopes. If the bush community is poorly represented it is principally because of shallow soil. A few scattered shrubs, e.g. *Rhus ciliata*, occur here and there on slopes facing in any direction. As a result of the relative uniformity in the edaphic and climatic conditions the vegetation on the slopes is more or less similar in any direction and consists principally of xerophytic grasses and shrubs.

The vegetation of the randjies of the area under discussion can best be dealt with under two headings: (1) the karroid communities, north of Bloemfontein, and (2) the vegetation on the other randjies of the area.

1. THE KARROID COMMUNITIES NORTH OF BLOEMFONTEIN.

The area of approximately 18 square miles directly north of the townlands of Bloemfontein, which was studied by Potts and Tidmarsh (1937), contains patches of typical karroid vegetation which differs markedly from that of the rest of the area studied. Except for a small patch of approximately one square mile a mile north of Tafelkop (approximately one mile north-east of the abovementioned karroid area; see map No. 3) no further samples of karroid communities were found.

Since 1937 the township of Bloemfontein has extended rapidly towards the north so that parts of the karroid area have been divided into small plots or have been occupied by homesteads.

The following description of the karroid communities is based on the writer's observations on the farm Tafelkop supplemented, by data taken from Potts and Tidmarsh (1937).

(*a*) Eberlanzia spinosa—Euphorbia mauritanica Community.

This community occurs on the rocky koppies and flat rocky bults on the farms Tafelkop, Mooihoek, Bayswater and Lilyvale in the Bloemfontein area. The community occupies the most xeric habitat in the Bloemfontein–Brandfort area. An abundance of large flat exposed rock surfaces occurs and the soils are scanty and shallow. The vegetation is also fully exposed to the desiccating effects of sun and winds.

In this community the spinescent succulent shrub *Eberlanzia spinosa* (see photo 6) and the stem succulent *Euphorbia mauritanica* are dominant and attain a height of 2 to 3 feet. Typically associated with these two succulents are the dwarf-shrub *Eriocephalus spinescens* and a few grasses, e.g. *Aristida canescens*, *Eustachys paspaloides*, *Digitaria eriantha* and *Heteropogon contortus*. These plants are usually found in narrow bands or lines following the clefts. On shallow gravelly soil at the rock edges pioneer grasses like *Eragrostis denudata*, *E. obtusa*, *E. atherstonei*, *Aristida congesta* and *Lepturella capensis* occur. The cushion-like succulents *Stomatium mustellinum* and *S. ermininum* and the tufted succulents *Anacampseros ustulata* and *Ruschia uniclens* occur on the shallow soil at the edges of the flat exposed rock surfaces. Where the root system of these plants fails to find interstices into which to penetrate, a spreading horizontal root system is formed on top of the rock surface, often not more than a few inches deep.

The pink lichen *Lecidea decipiens* Ach. is found on the bare shallow gravel soils and edges of the flat rock surfaces. It occurs in small, dense and depressed colonies approximately one inch in diameter. Mats of *Riccia* spp. are less frequently found after rains on shallow soils among the grasses and shrubs, but are not restricted to this community.

The succulent *Eberlanzia spinosa* forms dense clumps and normally wind-blown and water-washed sand and litter collect around its base. These sites are also partially shaded and harbour small colonies of plants which are very seldom met with elsewhere. The most common and characteristic species are the succulents *Senecio radicans* and *Sarcostemma viminale*. *Senecio radicans* is often also encountered at the base of rocks where it inhabits a shallow, wind-blown soil. As has been indicated by Potts and Tidmarsh the violet-flowered *Heliophila suavissima* grows up through *E. spinosa* and its flowers are conspicuous in autumn (see photo 6). For further details see the belt transects etc., of Potts and Tidmarsh.

(*b*) Euryops sulcatus var. densifolius—Euphorbia mauritanica Community.

This community is also encountered on rocky koppies on the farms Tafelkop, Mooihoek, Bayswater and Lilyvale, immediately north of Bloemfontein where the soil between the stones and boulders is deeper. Bare and exposed rock surfaces are not as extensive as in the *Eberlanzia spinosa–Euphorbia mauritanica* community.

In this community *Eberlanzia spinosa* is replaced by *Euryops sulcatus* var. *densifolius*, a much branched shrub, 2 to 3 feet high. The grass species occurring on the former habitat are also present but because of a deeper and more uniform soil cover they are better and more densely developed. Where shallow soil occurs *Eragrostis denudata*, *Aristida congesta* and *Lepturella capensis* are still evident. The most common herbs and shrublets are *Geigeria africana* and *Sutera argentea*. *Crassula schmidtii*, *Pellaea hastata* and *Cheilanthes hirta* are often at the base and in the shade of the boulders. *Olea africana*, a drought resistant tree is occasional on the karroid koppies north of Tafelkop.

It was interesting to note that Potts and Tidmarsh recorded *Duvalia corderoyi* as a chasmophyte in the karroid communities on the three farms north of Bloemfontein. *D. corderoyi* was not found in the karroid communities on the farm Tafelkop but there were many plants of the succulent *Trichodiadema pomeridianum*, which Potts and Tidmarsh did not find in the karroid communities they studied.

The following rock chasmophytes occur in both the *Eberlanzia spinosa—Euphorbia mauritanica* and *Euryops sulcatus* var. *densifolius—Euphorbia mauritanica* communities: *Crassula platyphylla*, *Cotyledon deccussata*, *Adromischus trigynus*, *Stapelia flavirostris*, *Caralluma lutea*, *Kalanchoe paniculata* and *Sarcostemma viminale*. On the xeric koppies and bults on the farm Tafelkop the abovenamed species are better represented in the *Euryops sulcatus* var. *densifolius—Euphorbia mauritanica* than in the *Eberlanzia spinosa—Euphorbia mauritanica* community. In contrast to these findings Potts and Tidmarsh (1937), reported that the above-named species are well represented in the *Eberlanzia spinosa—Euphorbia mauritanica* community on the farms Mooihoek, Bayswater and Lilyvale, and are rare in the *Euryops sulcatus* var. *densifolius—E. mauritanica* community. The writer also observed that on the farms Mooihoek and Bayswater these chasmophytes are not as conspicuous in the last-named community as on the farm Tafelkop.

(*c*) Characteristic Species of the Communities.

The following species are largely confined to both the *Eberlanzia spinosa—Euphorbia mauritanica* and *Euryops sulcatus* var. *densifolius—Euphorbia mauritanica* communities and are not, or very occasionally, found in other communities in the Bloemfontein–Brandfort area: *Euphorbia mauritanica* (very occasionally found on other koppies, e.g. near Glen), *Adromischus trigynus*, *Sarcostemma viminale*, *Trichodiadema pomeridianum* (distribution limited), *Eriocephalus spinescens* and *Sutera argentea* (rare on other koppies, e.g. near Glen).

The following species are almost completely confined to the *Eberlanzia spinosa—Euphorbia mauritanica* community and can therefore be regarded as characteristic species of this community: *Eberlanzia spinosa* (exceptionally

also on a rocky bult five miles north-east of Glen), *Stomatium mustellinum*, *Anacampseros ustulata* (exceptionally also on a rocky bult five miles north-east of Glen), *Senecio radicans* (very rare in other communities), *Heliophila suavissima* (very rare in other communities).

Mr. J. P. H. Acocks states that the species named below are typical karroid species and are not normally found in the grassveld areas of the Orange Free State north of Bloemfontein. Most of these species have been recorded from the more arid districts of the southern Orange Free State as well as from the Kimberley district: *Euphorbia mauritanica*, *Heliophila suavissima*, *Senecio radicans*, *Sarcostemma viminale*, *Eriocephalus spinescens*, *Cotyledon decussata*, *Trichodiadema barbatum*, probably also *T. pomeridianum*, *Rhigozum obovatum* (not north of Karree) and *Euryops multifidus*.

No exact distributional records are available for *Eberlanzia spinosa* and *Stomatium mustellinum*.

2. THE VEGETATION ON THE OTHER RANDJIES OF THE AREA.

As has been indicated the majority of randjies in the area carry a vegetation which is not typically karroid. Generally these other randjies are best represented near Bloemfontein, Glen, Mazelspoort and south of Brandfort (see also map No. 3).

(*a*) Botanical Survey of Four Randjies.

Botanical surveys of the northern and southern slopes as well as the tops of four randjies were made more or less according to the Estimated Frequency List method as used by Acocks (see Chapter 4). Of these one can be classified as a koppie, two as ridges and one as a hill. All consist of dolerite.

(1) *Koppie on the Farm Glen Lyon.*

This koppie lies five miles south-west of the Glen College of Agriculture. It is approximately 200 feet high with a basal diameter of 250 yards. This koppie is oval with its two longest sides facing east and west. The slopes are rather steep, between 20° to 40°. On the southern slope large irregular boulders and rocks occur and the interspaces are filled with a soil which seems to be fairly deep. On the northern slope is a shallow soil with stones 1 inch to 1 foot in diameter. Where large boulders occur on both slopes they usually split vertically to form small clefts in which a number of chasmophytes grow.

The survey was made on 18th May, 1953, and result are given in Table 9 and Figure 5.

(2) *Ridge at Mazelspoort.*

This ridge occurs on the farm Klipdrift at Mazelspoort. It is approximately one mile long, 200 yards wide and 180 feet high. Its slopes, which face directly north and south respectively, are steep, the inclination varying between 30° and 40°. The soil on the northern slope is shallow and practically covered by rounded stones varying in diameter from 3 to 6 inches. On the southern slope are large boulders one foot or more in diameter, and the interspaces are well covered by a soil which seems to be a few feet deep and is densely covered by grasses, forbs, etc. The differences in the edaphic conditions on the northern and southern slopes of this ridge are well marked.

This ridge was surveyed on 20th May, 1953. Results are given in Table 9 and Figure 6.

TABLE 9.—*Plant Species Recorded on the Northern and Southern Slopes and Tops of Four Randjies. Estimated Frequency List Method.*

Species.	Height of Plants.	Koppie, Glen Lyon.			Ridge, Mazelspoort.			Ridge, Bishop's Glen.			Hill at Karree.			Degree of Presence out of 4.		
		N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.
A.—TREES AND SHRUBS.																
*Olea africana**	A	—	2	3	—	4	2	1	5	2	1	5	2	2	4	4
*Ehretia rigida**	A	—	2	1	—	—	—	1	2	1	1	3	—	2	3	2
*Buddleja salicifolia**	A	2	5	—	—	—	—	—	1	—	1	5	5	2	3	1
*Tarchonanthus minor**	A	2	1	2	—	—	—	1	2	3	—	—	—	2	2	2
Rhus undulata var. *burchellii**	A	—	5	—	—	3	—	—	4	—	1	4	—	1	4	—
*Rhus erosa**	A	—	4	3	—	2	—	—	4	—	—	—	—	—	3	1
*Grewia occidentalis**	A	—	—	3	—	2	—	—	3	—	—	5	—	—	3	1
Ziziphus mucronata	A	—	—	—	2	—	—	1	—	—	2	—	—	3	—	—
Acacia karroo	A	—	3	—	3	—	—	—	—	—	—	—	—	1	1	—
*Cussonia paniculata**	A	—	—	—	—	—	—	—	1	—	—	1	—	—	2	—
*Osyris compressa**	A	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—
*Rhus ciliata**	B	6	1	—	5	4	3	6	3	5	7	3	4	4	4	3
*Royena hirsuta**	B	—	3	—	—	3	—	—	4	—	—	—	—	—	3	—
*Euclea ovata**	B	2	4	—	—	—	—	—	5	—	—	—	—	1	2	—
*Indigofera patens**	B	—	—	2	—	—	—	—	—	—	5	—	—	1	—	1
Lotononis divaricata	B	—	—	—	—	4	—	—	—	—	—	—	—	—	1	—
Royena lycioides	B	—	—	—	—	4	—	—	—	—	—	—	—	—	1	—
*Cluytia pulchella**	B	—	—	—	—	—	—	—	—	—	—	2	—	—	1	—
*Gymnosporia buxifolia**	B	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—
Chrysocoma tenuifolia	C	3	—	—	4	2	—	1	1	—	5	2	—	4	3	—
*Lantana salviaefolia**	C	2	2	—	—	4	—	3	1	—	3	1	—	3	4	—
*Pentzia sphaerocephala**	C	4	4	—	—	—	—	—	—	—	—	—	—	1	1	—

*Characteristic species for the randjies. A = Plants higher than five ft.; B = Plants between two to five ft.; C = Plants between six in. to two ft. high; D = Plants less than six in. high.

TABLE 9.—*Plant Species Recorded on the Northern and Southern Slopes and Tops of Four Randjies. Estimated Frequency List Method* (contd.).

Species.	Height of Plants.	Koppie, Glen Lyon.			Ridge, Mazelspoort.			Ridge, Bishop's Glen.			Hill at Karree.			Degree of Presence out of 4.		
		N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.
A.—TREES AND SHRUBS.—*(Cont.)*																
*Aster filifolius**.....	C	5	2	—	—	—	—	—	—	—	—	—	—	1	1	—
*Pegolettia retrofracta**.....	C	3	2	—	—	—	—	—	—	—	—	—	—	1	1	—
Melolobium calycinum.....	C	4	—	—	1	—	—	—	—	—	—	—	—	1	—	—
Garuleum pinnatifidum.....	C	—	—	—	—	4	—	—	—	—	—	—	—	—	1	—
Indigofera cryptantha.....	C	—	—	—	3	—	—	—	—	—	—	—	—	1	—	—
*Asparagus suaveolens**.....	C	—	—	—	—	—	—	—	—	—	1	1	—	1	1	—
*Asclepias burchellii**.....	C	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—
NUMBER OF SPECIES FOR A		11	15	6	5	11	2	7	14	4	10	11	3	—	—	—
B.—GRASSES.																
(1) PERENNIAL GRASSES.																
Themeda triandra.....	C	7	7	—	3	8	—	4	7	6	4	7	6	4	4	2
Sporobolus fimbriatus.....	C	5	3	4	2	4	—	2	5	4	3	3	—	4	4	2
Cymbopogon plurinodis....	C	5	6	—	3	7	—	3	6	—	2	7	5	4	4	1
*Aristida canescens**.....	C	7	4	—	8	2	—	5	4	—	4	1	6	4	4	1
Heteropogon contortus.....	C	5	2	—	8	1	—	4	2	2	6	3	—	4	4	1
*Eustachys paspaloides**....	C	5	2	—	4	2	—	3	2	—	3	2	4	4	4	1
Eragrostis lehmanniana....	C	—	—	—	5	—	6	2	1	6	8	3	—	3	2	2
Enneapogon scoparius.....	C	—	—	6	5	—	6	5	1	3	2	—	—	3	1	3
Digitaria eriantha.....	C	2	2	—	—	6	—	1	5	—	2	2	—	2	4	—

*Characteristic species for the randjies. A = Plants higher than five ft.; B = Plants between two to five ft.; C = Plants between six in. to two ft. high; D = Plants less than six in. high.

TABLE 9.—*Plant Species Recorded on the Northern and Southern Slopes and Tops of Four Randjies. Estimated Frequency List Method* (contd.).

Species.	Height of Plants.	Koppie, Glen Lyon.			Ridge, Mazelspoort.			Ridge, Bishop's Glen.			Hill at Karree.			Degree of Presence out of 4.		
		N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.
B.—GRASSES.—*(Cont).*																
Eragrostis atherstonei.....	C	3	2	—	3	—	—	5	4	—	1	1	—	4	3	—
Eragrostis obtusa.....	C	4	3	—	—	—	1	—	—	—	6	5	3	2	2	2
*Rhynchelytrum repens**....	C	2	—	—	5	—	—	6	—	—	7	1	—	4	1	—
*Triraphis andropogonoides**.	C	3	3	—	—	—	1	6	5	—	—	—	—	2	2	1
Digitaria monodactyla.....	C	—	—	—	3	2	—	—	—	—	2	1	—	2	2	—
Eragrostis curvula.....	C	—	—	5	—	4	—	—	1	—	—	—	—	—	2	1
Elyonurus argenteus.....	C	—	—	—	—	—	—	—	—	—	4	1	2	1	1	1
Eragrostis chalcantha.....	C	6	3	—	—	—	—	—	—	—	—	—	—	1	1	—
Aristida uniplumis var. *neesii**.....	C	—	—	—	3	—	—	4	—	—	—	—	—	2	—	—
*Brachiaria serrata**.....	C	3	3	—	—	—	—	—	—	—	—	—	—	1	1	—
Eragrostis denudata.....	C	—	—	—	—	—	—	3	—	—	1	—	—	2	—	—
Panicum maximum.....	C	—	—	—	—	—	—	—	—	—	1	2	—	1	1	—
*Cymbopogon excavatus**...	C	—	—	—	—	—	—	1	2	—	—	—	—	1	1	—
*Rhynchelytrum setifolium**..	C	—	—	—	5	—	—	—	—	—	—	—	—	1	—	—
Aristida vestita.....	C	—	—	—	—	—	—	—	—	—	4	—	—	1	—	—
Eragrostis superba.....	C	—	—	—	—	—	—	—	—	—	4	—	—	1	—	—
Fingerhuthia africana.....	C	—	—	—	3	—	—	—	—	—	—	—	—	1	—	—
(2) PIONEER GRASSES.																
Aristida congesta.....	C	7	5	1	7	2	—	4	4	6	8	6	1	4	4	3
Tragus koelerioides.....	D	7	4	—	6	2	—	6	6	1	8	4	5	4	4	2
NUMBER OF SPECIES FOR B		15	14	4	16	11	4	17	15	7	20	16	8	—	—	—

*Characteristic species for the randjies. A = Plants higher than five ft.; B = Plants between two to five ft.; C = Plants between six in. to two ft. high; D = Plants less than six in. high.

TABLE 9.—*Plant Species Recorded on the Northern and Southern Slopes and Tops of Four Randjies. Estimated Frequency List Method* (contd.).

Species.	Height of Plants.	Koppie, Glen Lyon.			Ridge, Mazelspoort.			Ridge, Bishop's Glen.			Hill at Karree.			Degree of Presence out of 4.		
		N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.
C.—FORBS AND SHRUBLETS. (1) *Heliophilous* spp.																
Aster muricatus.....	D	3	2	—	3	3	—	5	5	—	1	2	—	4	4	—
Selago albida.....	C	4	4	—	3	3	—	1	5	—	1	2	—	4	4	—
Stachys hyssopoides.....	C	1	7	—	—	5	—	5	6	5	1	—	—	3	3	1
Rhynchosia totta.....	C	2	2	—	3	2	—	—	—	—	1	5	—	3	3	—
Euphorbia maderaspatensis.	D	4	—	—	—	—	—	1	2	—	5	2	—	3	2	—
Anthospernum rigidum....	C	2	1	—	—	—	—	1	6	—	2	—	—	3	2	—
Helichrysum dregeanum....	D	5	2	—	3	6	—	—	—	—	—	—	—	2	2	—
*Chascanum pinnatifidum**...	D	2	—	—	5	—	—	4	—	—	4	—	—	4	—	—
Argyrolobium pauciflorum..	C	3	3	—	2	4	—	—	—	—	—	—	—	2	2	—
*Crassula platyphylla**.....	D	2	2	—	—	—	—	6	1	—	—	—	—	2	2	—
Hibiscus atromarginatus...	C	3	3	—	—	—	—	—	—	—	2	2	—	2	2	—
*Dianthus nicropetalus**....	D	2	2	—	—	—	—	1	2	—	—	—	—	2	2	—
Tephrosia capensis.....	C	—	—	6	—	—	—	4	—	—	4	—	—	2	—	1
*Kalanchoe paniculata**.....	C	2	—	—	—	—	—	4	—	—	2	—	—	3	—	—
Barleria macrostegia.....	D	2	2	—	3	—	—	—	—	—	—	—	—	2	1	—
Bidens pilosa.....	C	—	—	—	—	—	—	—	—	—	7	2	—	1	1	—
*Sutera albiflora**.....	D	2	—	—	—	—	—	—	—	—	5	—	—	2	—	—
Ruschia rigens.....	D	—	—	—	—	—	—	1	5	—	—	—	—	1	1	—
Senecio burchellii.....	C	3	3	—	—	—	—	—	—	—	—	—	—	1	1	—
Blepharis molluginaefolia...	D	—	1	—	3	—	—	—	—	—	—	—	—	1	1	—
Lasiosiphon capitatus.....	C	—	1	—	3	—	—	—	—	—	—	—	—	1	1	—

*Characteristic species for the randjies. A = Plants higher than five ft.; B = Plants between two to five ft.; C = Plants between six in. to two ft. high; D = Plants less than six in. high.

TABLE 9.—*Plant Species Recorded on the Northern and Southern Slopes and Tops of Four Randjies. Estimated Frequency List Method* (contd.).

Species.	Height of Plants.	Koppie, Glen Lyon.			Ridge, Mazelspoort.			Ridge, Bishop's Glen.			Hill at Karree.			Degree of Presence out of 4.		
		N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.
C.—FORBS AND SHRUBLETS—*(Cont.)*																
Lightfootia tenella	C	—	—	—	—	—	—	1	3	—	—	—	—	1	1	—
Osteospermum leptolobum	C	2	2	—	—	—	—	—	—	—	—	—	—	1	1	—
*Euphorbia catervaeflora**	C	—	1	—	—	—	—	—	—	—	2	—	—	1	1	—
*Pupalia lappacea**	C	—	—	—	—	—	—	—	—	—	2	1	—	1	1	—
Geigeria africana	D	—	—	—	—	—	—	—	—	—	1	2	—	1	1	—
Chenopodium album	C	—	—	—	—	6	—	—	—	—	—	—	—	—	1	—
*Annesorrhiza macrocarpa**	C	—	—	—	—	5	—	—	—	—	—	—	—	—	1	—
*Berkheya kuntzei**	C	—	—	—	—	5	—	—	—	—	—	—	—	—	1	—
Sutera aurantiaca	C	—	—	—	4	—	—	—	—	—	—	—	—	—	1	—
*Crabbea cirsioides**	D	—	3	—	—	—	—	—	—	—	—	—	—	—	1	—
Sutera atropurpurea	C	1	—	—	—	—	—	1	1	—	—	—	—	1	—	—
Aptosimum depressum	D	—	—	—	3	—	—	—	—	—	—	—	—	—	1	—
*Hermannia bryoniaefolia**	C	—	—	—	—	—	—	3	—	—	—	—	1	—	—	—
Elephantorrhiza elephantina	C	2	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Indigofera alternans	C	2	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Lotononis laxa	D	—	—	—	—	—	—	—	2	—	—	—	—	—	1	—
Tribulus terrestris	D	—	—	—	—	—	—	2	—	—	—	—	—	1	—	—
Zinnia multiflorum	C	—	—	—	—	—	—	2	—	—	—	—	—	1	—	—
Raphionacme hirsutum	C	—	—	—	2	—	—	—	—	—	—	—	—	—	1	—
Vernonia kraussii	C	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—
Solanum incanum	C	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—
(2) *Sciophilous* spp.																
*Cineraria aspera**	C	—	6	—	—	4	—	—	8	—	1	1	—	1	4	—
Oxalis depressa	D	—	6	—	—	8	—	—	6	—	—	2	—	—	4	—
Teucrium capense	C	—	—	—	—	3	—	—	—	—	5	1	—	1	2	—
*Senecio hastulatus**	C	—	5	—	—	—	—	—	3	—	—	—	—	—	2	—

* Characteristic species for the randjies. A = Plants higher than five feet; B = Plants between two to five feet; C = Plants between six inches to two feet high; D = Plants less than six inches high.

Species.	Height of Plants.	Koppie, Glen Lyon.			Ridge, Mazelspoort.			Ridge, Bishop's Glen.			Hill at Karree.			Degree of Presence out of 4.		
		N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.	N.	S.	Top.
C.—FORBS AND SHRUBLETS.—*(Cont.)*																
*Thunbergia dregeana**.....	C	—	—	—	—	—	—	—	—	—	1	3	—	1	1	—
Oxalis corniculatus.....	D	—	—	—	—	8	—	—	—	—	—	—	—	—	1	—
Helichrysum capillaceum...	D	—	—	—	—	—	—	—	8	—	—	—	—	—	1	—
*Crassula schmidtii**.....	D	—	—	—	—	—	—	—	6	—	—	—	—	—	1	—
*Nemesia hanoverica**.....	D	—	5	—	—	—	—	—	—	—	—	—	—	—	1	—
D.—GEOPHYTES.																
(1) *Heliophilous* spp.																
*Albuca setosa**.....	D	1	1	—	—	—	—	—	—	—	—	—	—	1	1	—
Babiana sp.*.....	D	—	—	—	—	4	—	—	—	—	—	—	—	—	1	—
Hypoxis sp.....	C	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—
Boöphone disticha.....	C	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—
(2) *Sciophilous* spp.																
*Massonia greenii**.....	D	—	5	—	—	3	—	—	—	—	1	6	—	1	3	—
Haemanthus sp.*.....	D	—	—	—	—	—	—	—	5	—	—	2	—	—	2	—
E.—FERNS.																
*Pellaea calomelanos**.....	C–D	4	4	—	1	2	—	1	2	—	2	2	—	4	4	—
*Cheilanthes hirta**.....	C–D	3	6	—	—	3	—	1	7	—	3	3	—	3	4	—
*Ceterach cordatum**.....	C–D	—	—	—	—	3	—	—	—	—	—	—	—	—	1	—
TOTAL NUMBER OF SPECIES FOR C, D AND E.....		23	28	1	14	18	—	18	19	1	21	16	—	—	—	—
GRAND TOTAL NUMBER OF SPECIES.....		49	57	11	35	40	6	42	48	12	51	43	11	—	—	—

* Characteristic species for the randjies. A = Plants higher than five feet; B = Plants between two to five feet; C = Plants between six inches to two feet high; D = Plants less than six inches high.

(3) *Ridge on the Farm Bishop's Glen.*

A botanical survey of a ridge on the farm Bishop's Glen was made on 10th March, 1954. This ridge is three miles south-east of the Glen College of Agriculture. It is half a mile long, 200 feet high, and has a basal diameter of 200 yards. The slopes are steep, varying between 30° and 40°, and two face directly north and south. Rocks and boulders are common on both, but there is more and deeper soil on the southern slope. Results are presented in Table 9.

(4) *Hill near Karree.*

The northern and southern slopes of a hill north of Karree Siding were botanically surveyed on 11th March, 1954. This hill is one third of a mile long and half a mile broad, with its longest sides facing more or less north and south. It is 150 feet high and it slopes are steep varying also between 25° to 35°. The survey was made on the eastern end of the ridge. The top of the hill, where the survey was made, just as in the other randjies surveyed, is narrow (20 to 40 yards wide). Rocks and boulders are abundant on both slopes. A deep soil is found on the higher levels of the northern slopes but on the lower level the soil is shallower. Although the soil on the southern slope is fairly deep there are rock surfaces with clefts in which individual plants occur as chasmophytes. Results of the surveys are given in Table 9.

(5) *Comparison of the Four Randjies.*

The four randjies studied do not vary much in height but there is a clear difference in their form and orientation. It can be expected that a single oval shaped koppie (No. 1) would not influence the micro-climate on the different slopes as much as the large east-west ridges. Consequently the differences in the edaphic conditions on the northern and southern slopes of the koppie studied are not as marked as those on the corresponding slopes of the hill and ridges.

The soil on the southern slope of the koppie near Glen is not so abundant and deep as that on the southern slopes of the ridges and hill studied. On the other hand the typical form of exfoliation of the dolerite with numerous small rounded boulders is found only on the northern slope of the ridge at Mazelspoort. On the northern slope of the koppie near Glen, on the ridge on the farm Bishop's Glen, and on the hill near Karree, small rounded boulders as well as large rocks with clefts and cracks occur. The differences in the micro-climatic and edaphic conditions on the northern and southern slopes of these randjies causes a rather striking difference in their vegetation.

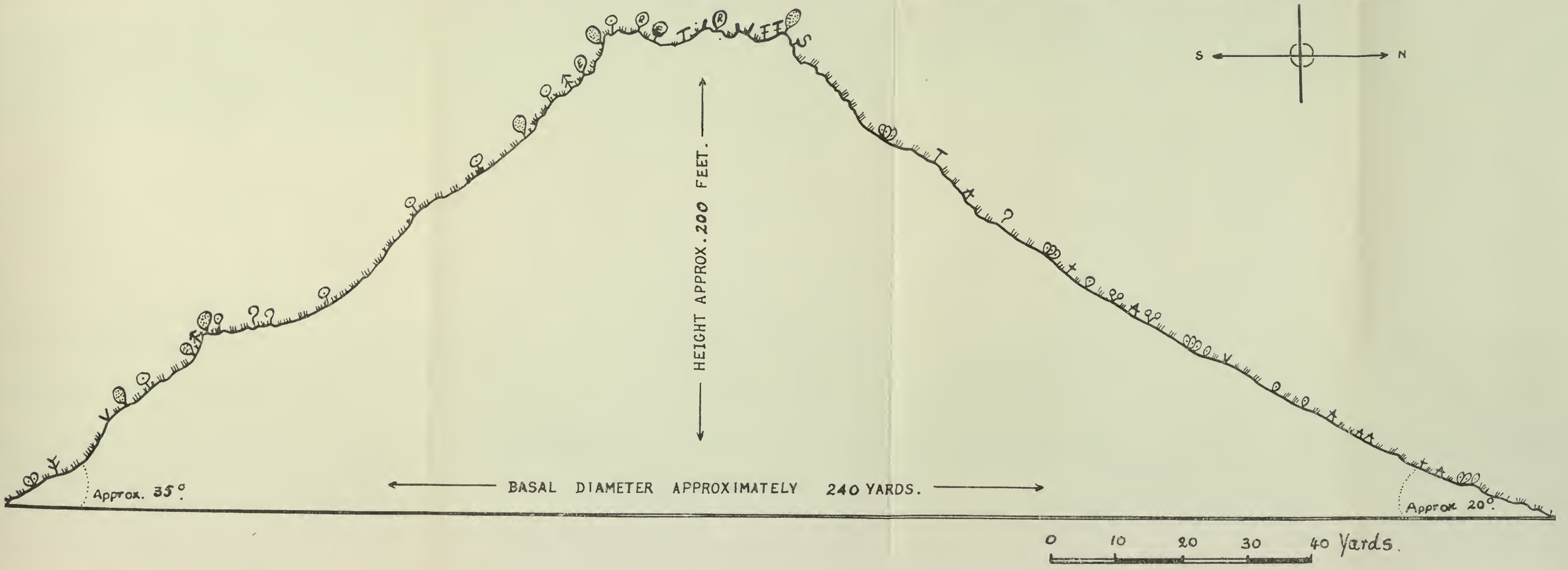
(*b*) Discussion of the Vegetation on the Randjies.

The species in Table 9 are arranged into five main groups, i.e. Trees and Shrubs, Grasses, Forbs and Shrublets, Geophytes, and Ferns. According to their height the trees and shrubs are divided into three sections. The species in all groups and sections are arranged according to the total value of their degree of presence on the slopes and top. The total number of species recorded on the randjies varies as follows:—

Northern Slope.	*Southern Slope.*	*Top.*
35 to 51.	40 to 57.	6 to 12.

FIGURE 5.

BOTANICAL SURVEY OF THE NORTHERN AND SOUTHERN SLOPES OF A KOPPIE NEAR GLEN.



REFERENCE:

- ACACIA KARROO HAYNE.
- ASTER FILIFOLIUS VENT.
- CHRYSOCOMA TENUIFOLIA BERG.
- EHRETIA RIGIDA BURCH.
- EUCLEA OVATA BURCH.
- EUPHORBIA CATERVIFLORA N.E. Br.
- GRASSES AND OTHER HERBACEOUS PLANTS.
- GREWIA OCCIDENTALLS L.
- INDIGOFERA PATENS E. & Z.
- MELOLOBIUM CALYCINUM BENTH.
- OLEA AFRICANA MILL.
- OSYRIS COMPRESSA A.D.C.
- PEGOLETTIA RETROFRACTA. P. KIES
- RHUS CILIATA LICHT.
- RHUS EROSA THUNB.
- RHUS UNDULATA VAR. BURCHELLII SCHONL.
- TARCHONANTHUS MINOR LESS.

On the basis of these figures only it is difficult to say whether there is any significant difference in the number of species on the northern and southern slopes and the top, for the areas surveyed usually differ markedly in size. That the number for the top is so much lower is not surprising for the top is very much smaller than the slopes.

(1) *Dry Northern and Western Slopes.*

On the dry northern and western slopes of randjies where the soil is shallow and consists chiefly of gravel with numerous small boulders the arborescent vegetation is poorly developed or absent. The vegetation consists chiefly of grasses, forbs and shrublets which are well developed on the open spaces between the scattered shrubs of which *Rhus ciliata* is the most important. The percentage cover of these species depends principally on the amount of top soil present.

(i) *Layers.*

On the northern slope three plant layers can be recognised:—

(*a*) Tree layer. (Higher than five feet.)

(*b*) Shrub layer. (Two to five feet high.)

(*c*) Grass-forb layer. (Six inches to two feet high.)

The trees occurring on the north-western slopes are not grouped but occur singly.

As can be seen from Table 9 the shrub layer is well represented on the drier slopes. It consists principally of *Rhus ciliata* (see photo 7), *Chrysocoma tenuifolia* and *Lantana salviaefolia*. *Rhus ciliata* occurs in extensive dense patches scattered on the northern slopes, particularly on the lower levels.

The soil between the stones and boulders is usually covered by grasses, forbs and shrublets which, next to the *Rhus ciliata* community, form the dominant vegetation on the dry slopes.

(ii) *Characteristic Species on the Northern Slopes.*

From Table 9 it can be concluded that of the 29 tree and shrub species occurring on the randjies only one species can be regarded as characteristic for the northern slopes, viz. *Rhus ciliata*. Although this species was also constantly recorded from the southern slopes it occurs in much larger numbers and in greater patches on the drier slopes. (See photo 8.) It was interesting to note that *Ziziphus mucronata* is present mostly on the northern randjie slopes. It occurs, however, only sparsely and can be regarded as an outlier from the surrounding valleys in which it occurs abundantly.

Tarchonanthus minor seems to have no preference as regards the dry or moister slopes.

From Table 9 it can be seen that 27 grass species were recorded from the dry slopes.

Of the grasses only two species, i.e. *Rhynchelytrum repens* and *Aristida uniplumis* var. *neesii* are almost entirely restricted to the drier slopes; the former is abundant; the latter, although it was found on several other randjies, was recorded on only two of the four randjies surveyed. Of the

other characteristic species of the randjies which are shown in Table 9 *Aristida canescens* and *Eustachys paspaloides* (a broad-leaved grass) are constantly present on both slopes but are much more abundant on the drier than on the moister slopes.

Many grass species on the randjies belong more characteristically to the grassveld communities on the bults and plains. Of these species the following are the most abundant: *Themeda triandra*, *Cymbopogon plurinodis*, *Sporobolus fimbriatus* and *Heteropogon contortus*. Although these grasses do not seem to have any marked preference for a definite aspect, they occur, except *H. contortus*, mostly on the southern slopes. *Cymbopogon excavatus*, *Rhynchelytrum setifolium* and *Brachiaria serrata* were recorded on only one of the four surveyed randjies, yet they have been found on other randjies and confined to the northern slopes.

Of the 11 heliophilous forbs and shrublets which are characteristic species of the randjies (see Table 9), only three, i.e. *Chascanum pinnatifidum*, *Kalanchoe paniculata* and *Sutera albiflora*, are found exclusively on the northern slopes. The first species is the most abundant. Many forbs and shrublets, e.g. *Aster muricatus*, *Selago albida*, *Stachys hyssopoides*, *Rhynchosia totta*, etc., occur in relatively large numbers but are more or less indifferent to the aspect and are also represented in the Themeda grassveld community.

In general the sciophilous forbs, shrublets and geophytes are either absent or poorly represented on the drier slopes. A few heliophilous geophytes occur on the northern slopes but are rather rare.

Of the ferns, *Cheilanthes hirta* and *Pellaea calomelanos* occur on both slopes but are restricted to shady and sheltered spots. The " resurrection fern " *Notholaena eckloniana* was not recorded in the surveys of the four randjies but is often found on other randjie slopes, in the protection of rocks.

(iii) *The Rhus ciliata Community.*

Rhus ciliata communities were studied on the slopes of various randjies in this area, e.g. at Karree, Mazelspoort, Glen and on the farms Glen Lyon (see photo 7) and Bishop's Glen. As can be seen from Table 9 *Rhus ciliata* occurs abundantly on the northern and southern slopes as well as on the top of the randjies surveyed. This thorny much-branched shrub grows gregariously and forms dense clumps 1 to 4 feet high, and often 10 yards or more in diameter, spreading outwards from the margins of the clumps by means of suckers.

It appeared that the following species, enumerated more or less in order of frequency, are often associated with *R. ciliata*.

On Southern Slopes—
Themeda triandra,
Cymbopogon plurinodis,
Digitaria eriantha,
Senecio hastulatus,
Oxalis spp.,
Rhynchosia totta.

On Northern Slopes—
Themeda triandra,
Heteropogon contortus,
Aristida canescens,
Triraphis andropogonoides,
Digitaria monodactyla,
Rhynchosia totta.

Occasionally on the farms Glen Lyon and Tafelkop either *Rhus undulata* var. *burchellii* or *Buddleja salicifolia* grows in the centre of a dense patch of *Rhus ciliata.*

In this area animals apparently do not browse *R. ciliata* but the seeds are eaten and dispersed by birds. Although its leaves have a high protein content, up to 16·19 per cent, Henrici (1935), also noted that this shrub is not eaten by stock. Wilman (1946), on the other hand, stated that it is excellent stock feed in the Griqualand West area.

(iv) *Colonization of the Northern and Western Randjie Slopes.*

The rock-colonizing species can be readily studied on the bare rock surfaces on the crests and slopes of the randjies. The first invaders of the bare rock surfaces are the dark or brown coloured crustose lichens. As the doleritic rocks are very resistant these lichens apparently accomplish very little in initiating the disintegration of the rocks, but as a result of their chemical action a rough rock surface may be formed.

As these rocks and boulders eventually become weathered and crevices are formed, humus and other material collects in these cracks. Small chasmophytes, e.g. *Anacampseros telephiastrum*, *A. rufescens* and *Schizobasis cuscutoides* are commonly found. The succulent *Crassula platyphylla* is also a common chasmophyte and all these species are not only drought resistant but have to grow in scanty soil, often under a wide range of temperatures. The ferns which are often encountered as chasmophytes on the southern hill slopes are more poorly represented on the northern slopes. *Cheilanthes hirta*, *Pellaea calomelanos* and *Notholaena eckloniana* are quite xerophytic and grow in shady spots at the base of boulders on the western and northern slopes. It was interesting to find *Schizobasis cuscutoides* growing in a narrow rock crevice on the top of a hill on the farm Glen Lyon. These small, shallowly rooted chasmophytic plants like the forbs, etc., will exert little pressure and can accomplish very little mechanically in the widening of the rock cracks. As the cracks widen *Crassula* spp., *Euphorbia* spp., *Cotyledon* spp. are most commonly encountered.

The following species are encountered as chasmophytes: *Aristida canescens*, *Eustachys paspaloides*, *Triraphis andropogonoides*, *Euphorbia catervaeflora*, *Euphorbia maderaspatensis*, *Melolobium calycinum*, *Aster filifolius* and *Rhus ciliata.*

(2) *Moister and Cooler Southern and Eastern Slopes.*

As stated previously, conditions are cooler and moister on the southern and eastern slopes of the randjies, the soil is deeper and the trees and shrubs as well as sciophilous species are much better represented than on the drier slopes. The vegetation on the southern slopes consists chiefly of trees and shrubs (see photos 8, 9 and 10) but the grasses and forbs are also well represented on the open situations between the arborescent vegetation.

(i) *Layers.*

On the south-eastern slopes at least four plant layers can be distinguished:—

(*a*) Tree layer. (Higher than five feet.)
(*b*) Shrub layer. (Two to five feet high.)
(*c*) Grass-forb layer. (Six inches to two feet high.)
(*d*) Ground layer. (Geophytes lower than six inches high.)

Arborescent and sciophilous species are markedly similar on the southern slopes of the four randjies surveyed. Trees and shrubs are usually larger and not as stunted as on the drier slopes. The trees and shrubs on the southern slopes of the randjies may either be evenly spread or may occur in patches (see photos 8 and 9). On the hill at Karee the trees are densely and evenly spread over the entire southern slope. On the southern slopes of the other randjies surveyed the trees are in clumps.

The species composition of some seven clumps investigated on the farms Glen Lyon and Bishop's Glen is given below:—

Trees and Shrubs—	Undergrowth—
(*a*) *Olea africana* (dominant), *Rhus erosa* (sub-dominant), *Rhus undulata* var. *burchellii*, *Cussonia paniculata*, *Euclea ovata*.	*Cineraria aspera* (dominant), *Helichrysum* sp., *Oxalis depressa*, *Sporobolus fimbriatus*.
(*b*) *Olea africana* (dominant), *Rhus erosa* (sub-dominant), *Euclea ovata*.	*Cineraria aspera* (dominant), *Setaria verticillata*, *Cheilanthes hirta*, *Lantana salviaefolia*.
(*c*) *Olea africana* (dominant), *Euclea ovata* (sub-dominant).	*Cineraria aspera* (dominant), *Helichrysum* sp., *Setaria verticillata*, *Crassula schmidtii*.
(*d*) *Olea africana* (three trees).	*Rhus ciliata* (dominant), *Rhus erosa* (small shrub), *R. undulata* var. *burchellii*, *Cineraria aspera*.
(*e*) *Rhus undulata* var. *burchellii* (two trees).	*Cineraria lyrata* (dominant), *Oxalis* sp., *Sporobolus fimbriatus*.
(*f*) *Olea africana* (dominant), *Buddleja salicifolia*.	*Haemanthus* sp. (dominant), *Digitaria eriantha*, *Massonia greenii*, *Cheilanthes hirta*.
(*g*) *Rhus erosa*.	*Lepidium divaricatum* (dominant), *Chenopodium album*, *Oxalis* spp., *Setaria verticillata*.

The drought resistant evergreen *Rhus erosa* usually occurs as a large solitary shrub 6 to 10 feet high and 5 to 10 feet in diameter. The following species were occassionally found in its shade: *Cineraria aspera*, *Chenopodium album*, *Lepidium divaricatum*, *Oxalis* spp., *Cheilanthes hirta*.

Generally the shade cast by *Rhus undulata* var. *burchellii* and *R. erosa* is so dense that undergrowth is absent or poorly developed. A dense mycelium is often found in the decomposing litter.

Grasses and forbs are well represented on the cooler slopes. The mesophytic grasses, e.g. *Themeda triandra* and *Cymbopogon plurinodis* are examples.

The ground layer on shady cool spots consists principally of mosses and geophytes with leaves adpressed against the soil surface. These plants are well represented underneath the trees, at the base of boulders and in the shade of the rocks. They often form dense patches.

(ii) *Characteristic Species of the South-eastern Slopes.*

From Table 9 it can be concluded that, of the 21 species of trees and shrubs characteristic of the randjies in general, at least nine species can be regarded as characteristic of the southern slopes. *Rhus erosa* and *Grewia occidentalis* (occasionally also found on the top of the randjies) *Olea africana*, *Buddleja salicifolia* and *Ehretia rigida* (recorded also on both slopes and on the top of the randjies) are all common. See photos 8, 9 and 10.

The following species were recorded on 1 to 3 of the randjies: *Cussonia paniculata*, *Osyris compressa*, *Royena hirsuta* and *Clutia pulchella*.

Rhus ciliata and *Lantana salviaefolia* are constantly present on the southern slopes but are most abundant on the northern slopes.

Aster filifolius, *Pentzia sphaerocephala* and *Pegolettia retrofracta* are relatively indifferent to the various aspects of the slopes.

No single grass species is found exclusively on the southern slopes. *Eragrostis curvula* was recorded in one stand only but can hardly be considered as a characteristic species. It usually occurs in Themeda and Valley–Vlei grassveld.

Many forbs and shrublets occur on the randjies but are not confined to this habitat. Some of these species, e.g. *Aster muricatus*, *Selago albida* and *Stachys hyssopoides*, are common on the randjies but are more typical of the valleys. Only three of the 11 species of heliophilous forbs and shrublets, which occur almost exclusively on the randjies, are confined to the southern slopes. These are *Crabbea cirsioides*, *Annesorrhiza* sp. prob. *A. macrocarpa* and *Berkheya kuntzei*. They were not recorded on all four randjies surveyed, but were found on other randjies in this area.

Of the sciophilous forbs, two species, *Cineraria aspera* and *Oxalis depressa*, are constantly present on the southern slopes, the former abundantly. *Nemesia hanoverica*, *Senecio hastulatus*, *Helichrysum capillaceum* and *Crassula schmidtii* are characteristic of the southern slopes, but were present in only 1 or 2 of the stands examined.

Of the geophytes the sciophilous *Massonia greenii* was common on the southern slopes and occasional in shady spots on the northern slopes. *Haemanthus* sp. is present on the cooler slopes only. With the exception of *Ceterach cordatum*, which was found in one stand on the southern slope only, all the ferns occur on both slopes.

(iii) *Colonization of the Southern and Eastern Slopes.*

The bare rock surfaces on the randjies are, in many spots, well covered by lichens which form large patches. This is well illustrated on the hill slopes at Karree siding. In contrast to the crustose lichens of the dry northern slopes those occurring on the southern slopes are usually foliose and glaucous or silver-whitish. On the rough, shaded rock surfaces, especially where a little soil or debris occurs, mosses are the first pioneers. Extensive mats, nearly one foot square, have been found on shaded moist soil at the foot of boulders on the hills near Mazelspoort. The sides of

small stones may become almost totally covered by them (see photo 11). Early invaders of the crevices are the chasmophytic ferns and liverworts. The ferns are well represented and have somewhat extensively developed root systems. *Cheilanthes hirta* and *Pellaea calomelanos* are drought resistant and abundant at the base of boulders on slopes facing south and east.

As the rock crevices become wider, the ferns are usually replaced by chasmophytic grasses, shrubs and trees. The following species have often been found: the succulents *Crassula* spp. and *Euphorbia* spp., the shrubs *Asparagus suaveolens*, *Argyrolobium* sp. and *Lantana salviaefolia*, and the trees *Olea africana* and *Grewia occidentalis*.

(3) *Vegetation on Top of the Randjies.*

Except on a few large hills, e.g. Naval Hill, Keeromsberg, etc., the tops of the randjies in this area are much smaller than their slopes. As on the slopes, the percentage cover of the tops depends principally on the amount of soil present. The tops of the randjies are often stony or gravelly and do not carry a dense cover or large variety of species.

From Table 9 it can be seen that the total number of species observed in the line transect on the relatively small tops surveyed varied between 6 and 12.

The vegetation on top of the randjies can also be divided into three layers:—

(1) Tree layer. (Higher than five feet.)
(2) Shrub layer. (Two to five feet high.)
(3) Grass-forb layer. (Six inches to two feet high.)

On the tops the trees are in general more abundant than on the northern slopes, but they are not as dense or as abundant as on the southern slopes. Normally the trees occur singly. The most common of the trees and shrubs, are *Rhus ciliata*, *Olea africana*, *Ehretia rigida*, *Tarchonanthus minor*, *Buddleja salicifolia*, *Rhus erosa* and *Indigofera patens*.

In general the forbs, shrublets and ferns are poorly represented or absent. *Aster muricatus* and *Chrysocoma tenuifolia* are occasionally found.

From Table 9 it can be seen that the grasses are well represented on the tops of the randjies. The most abundant species, are: *Aristida congesta*, *Themeda triandra*, *Sporobolus fimbriatus*, *Enneapogon scoparius*, *Eragrostis lehmanniana*, *Tragus koelerioides*, *Eragrostis obtusa*, *Aristida canescens*, *Cymbopogon plurinodis* and *Eustachys paspaloides*. No species was found to be restricted to the top of the randjies.

A comparison of the vegetation on the top of the randjies with that found on the northern and southern slopes, shows the following:—

(1) On both the northern and southern slopes characteristic species were found. No species were found to characterise the top.
(2) A denser cover of trees is found on the top than on the northern slopes of the randjies.
(3) Trees and shrubs are more abundant on the southern slopes than on the tops.
(4) A sciophilous undergrowth is found on the southern slopes but is absent or scanty on the tops of the randjies.

In general there is a close similarity between the climate and vegetation on the top and that on the northern slopes of the randjies.

(4) *Vegetation in the Kloofs of the Randjies.*

As has been said the kloofs between randjies, independent of aspect, are usually densely covered by trees, as a result of better soil and water conditions.

The botanical composition of a few kloofs on the farms Glen Lyon and Bishop's Glen, was studied in March, 1954. The vegetation of the kloofs can also be divided into three layers:—

(1) Tree layer. (Higher than five feet.)

(2) Grass-forb layer (Six inches to two feet.)

(3) Ground layer. (Lower than six inches high.)

The following trees are abundant: *Olea africana*, *Buddleja salicifolia*, *Grewia occidentalis*, *Rhus undulata* var. *burchellii*, *Tarchonanthus camphoratus* var. *litakunensis* and *Ziziphus mucronata*. The following are occasional : *Cussonia paniculata*, *Acacia karroo*, *Rhus lancea*, *Celtis africana* and *Rhus pyroides*.

Of the shrubs *Clutia pulchella* var. *obtusata* is the most common. *Rhus ciliata* is either absent or very poorly represented.

The trees in the kloofs are fairly robust, well intermixed and often form a closed canopy. This is especially evident on the lower slopes of the kloofs. Where a dense canopy occurs a poor undergrowth is encountered, consisting principally of sciophilous grasses and forbs. The following are some of the most common sciophilous species:—

Grasses—	Forbs—
Melica racemosus,	*Chenopodium album*,
Bromus catharticus,	*Cineraria aspera*,
Digitaria eriantha (also heliophilous),	*C. lyrata*,
Panicum maximum (also heliophilous),	*Senecio hastulatus*,
Setaria verticillata (also heliophilous).	*Oxalis* sp.

The ground layer is very sparse and consists principally of geophytes; the most abundant are *Massonia greenii* and *Haemanthus* sp.

On the edges of the kloofs and in places where the crowns of the trees do not form a dense canopy, heliophilous grasses, forbs and shrublets become more conspicuous.

With the exception of *Clutia pulchella* var. *obtusata* no species was found to be restricted to the kloofs.

(*c*) Utilization of Randjie-veld.

Generally the grasses on the randjies are of a more sour type than those found on the flats and in the valleys. They usually sprout in early spring, seed in summer, and are quite unpalatable in late summer and winter. The occurrence of a more sour grass type in stony places may perhaps be explained by Story's contention (1952), that the soil in rocky areas receives more useful water.

As a result of a predominating cover of shrubs, trees and relatively sour grasses the randjies in this area appear to have a great resemblance to those occurring in the higher rainfall areas of the eastern Orange Free State.

The best treatment is probably a careful early summer grazing system. The randjie camps are valuable to stock-farmers for the shelter which the trees afford to the animals.

(*d*) Further Notes on Plant Species occurring on the Randjies

In the foregoing discussion of the vegetation of the randjies the species mentioned were recorded by the Estimated Frequency List method of survey. These surveys do not, however, give a complete list of all the species found on the randjies. Many species were found on the randjies which have not yet been discussed. *Themeda triandra* and *Heteropogon contortus* occur also in other veld types in this region and since they constitute an important part of the vegetation on the randjies they must also be considered here.

The species discussed below are encountered on most of the randjies in this area except on the small xeric spots north of Bloemfontein (karroid area) where the Eberlanzia-Euphorbia and Euryops-Euphorbia communities are found.

The families are arranged according to Phillips (1951).

Gramineae.

The grasses are mesophytic to xerophytic types and often form a dense cover on the soil between the boulders and rocks.

Themeda triandra, *Heteropogon contortus* and *Sporobolus fimbriatus* are common on the hills, ridges and koppies but are more frequent on the flats and plains. It was rather surprising to find quite a large number of tufts of *Enneapogon scoparius* (see Table 9). This grass is more typical of limestone soils and outcrops, especially those which are overgrazed by sheep (see Chapter 8). A sample of the top soil to a depth of four inches taken on the top of the doleritic koppie on the farm Glen Lyon where a dense stand of *E. scoparius* occurs between the boulders was tested by Mr. M. C. F. du Plessis and showed a pH of 5·9. A high humus content was found in the top soil. The calcium content of the soil was high and it had 82 parts per million of soluble salts which is high in comparison with analyses of samples of limestone and sandy-loam soils (see Chapter 8).

Cymbopogon excavatus and *C. marginatus* are robust unpalatable grasses restricted to stony koppies and rises. They usually flower in late summer. In this area *Hyparrhenia hirta* and *Cenchrus ciliaris* are restricted to the tops and higher slopes of the larger hills and koppies. The first species is uncommon but has a wide distribution. The latter was found only on koppies near Mazelspoort. They afford good grazing. *Aristida canescens* and *A. uniplumis* var. *neesii* are robust but very fibrous and are only grazed by cattle when very young. Four species of *Eragrostis* are often found on the randjies: *E. atherstonei*, *E. denudata*, *E. gummiflua* and *E. truncata*. For details see section 2 (*b*).

Liliiflorae.

The robust *Anthericum paniculatum* attains a height of 2 to 3 feet and has numerous whitish flowers. It favours stony hill slopes and as it forms dense bunches it is conspicuous when in flower during spring. *Aloe grandidentata* and another species of *Aloe* (Mostert, No. 542), form dense patches on the slopes of hills. The former is occasional and the latter has only been found in two places, i.e. at Bloemfontein and directly north of Tafelkop. The leaf-tips of the Aloes are often damaged by frost during winter. *Rhadamanthus* sp. (Mostert, No. 720) and *Albuca* sp. (Mostert, No. 128), are two rare species which have been found on shallow shaly soils on the top of a hill near Glen. *Asparagus medeoloides* and *A. suaveolens* are frequent. The former species is a rambler and has beautiful bright green phylloclades. It is restricted to shady humus-rich soils on the southern and eastern slopes of hills near Glen. The latter is a hardy, white-flowered chasmophyte occurring on most of the randjies in this area.

Several species of *Hypoxis*, especially *H. rooperi*, occur between the grasses on hill slopes.

Gladiolus edulis and *Lapeyrousia galaxoides* occur singly on the slopes of hills and stony rises. The former is 2 to 3 feet high and has silvery-purple flowers. The latter is 1 to 2 inches high and has large creamy flowers. It favours pebbly slopes and is conspicuous only during seasons with heavy winter rains, as in 1950.

Santalaceae and *Ulmaceae.*

The chasmophytic deciduous tree *Celtis africana* and the evergreen shrub *Osyris compressa* are occasional on the hills and koppies. The former favours the southern slopes.

Aizoaceae.

Quite a number of species of this xerophytic family are commonly found on the randjies. *Ruschia hamata* and *R. unidens* are occasional on the slopes especially as pioneers. The first has a wide distribution and is consumed by stock. *R. caninotata* is frequent on open overgrazed places.

Caryophyllaceae.

Silene burchellii, *Dianthus micropetalus* and *D. scaber* are usually found on stony koppies and ridges.

Crasssulaceae.

Twelve of the 15 species found in this area occur on the hills, ridges and koppies. *Crassula platyphylla*, *C. muscosa* and *C. schmidtii* are the most common. The short-lived *Kalanchoe paniculata*, the perennial *K. rotundifolia* and the showy orange-flowered *Cotyledon decussata* are widely scattered on rocky randjies. These species are inedible to stock and the last-mentioned is poisonous (see Steyn 1934).

Leguminosae.

Elephantorrhiza elephantina is important. It is very thick-rooted and occurs gregariously on isolated places in Themeda grassveld and on the northern slopes of hills. *Lotononis laxa* and *L.* sp. cf. *L. bainesii* are thick-rooted herbs with conspicuous yellow flowers occurring on the stony slopes of koppies or as chasmophytes on rocky places. These plants are grazed by stock. The spinescent inedible yellow-flowered *Melolobium calycinum* favours deeper soils on the lower slopes of hills and rises.

Argyrolobium nanum is widely spread on stony koppie sides. This species is well rooted, edible and has yellow or orange-coloured flowers. *Indigofera patens* is an erect shrub confined to shallow rocky soils on the slopes and tops of koppies at Saltpan, Karree and Glen. It has small dark red flowers and has not been found on all the randjies in this area.

Geraniaceae.

Pelargonium aridum is a thick-rooted chasmophytic herb favouring shady places on the hill sides.

Euphorbiaceae.

A few species are widely scattered on randjies. *Euphorbia catervaeflora* is a spinelsss succulent, scattered on stony randjie slopes. *E. mauritanica* a common succulent on rocky bults north of Bloemfontein has been discussed. The succulent shrub *E. rectirama* forms thick stands on the koppies near Saltpan but has not been found on other koppies in this area.

Anacardiaceae.

In this area all except *Rhus pyroides* occur on the slopes of the hills and ridges. *Rhus undulata* var. *burchellii* is an evergreen tree, drought resistant and normally attaining a height of 8 to 10 feet. According to local farmers it is browsed during droughts. The evergreen *Rhus lancea* is common in the valleys but a few trees may also be seen on the cooler randjie slopes.

Celastraceae.

Gymnosporia saxatilis is frequent on the drier slopes of hills near Bloemfontein. It is very thorny, 1 to 3 feet high, with creamy flowers, and is very drought resistant.

Malvaceae.

The orange-flowered shrublet *Sida dregei* and the yellow-flowered *Hibiscus atromarginatus* are the most abundant species on the randjies. The former is usually in the shade of trees and the latter favours open situations. Both plants have thick and deep roots.

Sterculiaceae.

Only one species, i.e. *Hermannia bryoniaefolia* is normally encountered on the randjies. It generally occurs underneath the trees and has numerous orange-coloured flowers.

Cactaceae.

Various forms of the exotic genus *Opuntia* have become acclimatised and are widely spread on the randjies.

Araliaceae.

Cussonia paniculata occurs here and there on the southern slopes of the larger randjies. It attains a height of 10 to 15 feet and its blue-green crowns usually protrude through the canopy of other trees.

Ebenaceae.

Royena hirsuta, *Euclea ovata* and *Euclea lanceolata* are often found as chasmophytes. They are resistant against drought and not very palatable to stock.

Oleaceae.

The well known *Olea africana* is common especially on the cooler sides and in kloofs. It often occurs in large numbers with *Buddleja salicifolia* and *Grewia occidentalis*. The crowns of these species often form a dense canopy 10 to 12 feet high. *O. africana* is valuable for the shade and shelter it affords to animals. The leaves on its lower branches are browsed by stock and are kept short as far as animals are able to reach them. As a result of this it is striking that the majority of trees have a typical mushroom-shaped appearance with a flat underside to the crown (see photo 12).

Loganiaceae.

The evergreen tree *Buddleja salicifolia* attains a height of 10 feet and occurs abundantly, and its large panicles with numerous creamish flowers are conspicuous. It flowers more or less every summer but flowered most profusely in March, 1955—approximately five weeks after heavy rains (see photo 13). This tree is drought resistant and its greenish leaves are browsed by stock during periods of scarcity. According to Henrici (1940), the protein content of its leaves varies between 3·41 and 11·11 per cent.

Asclepiadaceae.

The mauve-flowered *Raphionacme hirsuta* and the greenish-flowered *R. zeyheri* are both perennial herbs with thick fleshy rootstocks and occur on open spots on the koppie slopes and rises. *Caralluma lutea*, a yellow-flowered succulent, and the purple-flowered *Stapelia flavirostris* are common and widely scattered on stony ridges, usually on loose soil between the stones.

Boraginaceae.

Ehretia rigida is a small tree 6 to 8 feet high occurring singly on the hills and koppies.

Verbenaceae.

Chascanum pinnatifidum and *Lantana salviaefolia* are the most common. The former occurs on open spots between the grasses especially on low ridges and has creamish flowers. The latter occurs as a chasmophyte on hills and koppies. It has mauve flowers and is not eaten by stock.

Solanaceae.

Solanum tomentosum favours shady places and is fairly common under trees on the hills. It may also occur on open bare spots. A species of *Solanum* (Mostert, No. 125), closely related to *S. tomentosum* was found on the top of a rocky hill near Glen.

Scrophulariaceae.

The showy purple-flowered shrublet *Aptosimum origanoides* occurs frequently. It is drought resistant and a valuable fodder plant. Several species of the genus Sutera, the white-flowered *S. albiflora*, the brown-flowered *S. atropurpurea* and the small orange-flowered *S. aurantiaca* are widely scattered. All these shrublets are well rooted and browsed by sheep, especially during the winter. The pink-flowered *S. pristisepala* is a strong undershrub occasionally found on hills. *Selago speciosa*, an erect creamish-flowered shrublet grows on the overgrazed slopes of koppies and is not eaten by stock. *Walafrida densifolia*, *W. paniculata* and *W. saxatilis* are perennial shrublets occasionally found on the lower slopes of koppies but are commoner as roadside pioneers.

Bignoniaceae.

Rhigozum obovatum is a hardy shrub 3 to 6 feet high which occurs here and there on the higher slopes of a few hills near Bloemfontein and Karee, but does not occur on all the randjies in this area and is not found north of Karree. Because of its large golden-yellow flowers it is the showiest shrub in this area. It was very conspicuous in October, 1952, but does not flower every year.

Acanthaceae.

Thunbergia dregeana, *Crabbea cirsioides* and *Barleria macrostegia* are the representatives of the family. The first-named species is a perennial herbaceous rambler with golden fugacious flowers, which is normally confined to shady situations on the eastern hill slopes. The second was encountered on the top and northern slopes of hills near Bloemfontein and Glen, and the last is a prostrate herb preferring open Themeda veld and the stony northern slopes of rises.

Campanulaceae.

The family is represented by three species of the genus *Lightfootia*: *L. albens*, *L. denticulata* and *L. tenella*. They are drought resistant and occur in great numbers, principally on the drier slopes, and are well browsed by animals.

Compositae.

The family is well represented on the randjies. Many species and individuals occur, sometimes attaining dominance, but they are usually well scattered and intermixed with other plant families and species. Some of our best fodder plants belong to this family. *Vernonia kraussii*, a shrubby purple-flowered species, forms dense gregarious patches on the lower hill slopes, e.g. near Glen. As far as could be ascertained it is not eaten by stock. *Aster filifolius* is a shrub 2 to 3 feet tall and has numerous showy mauve flowers which are conspicuous in late winter. It often occurs in dense patches on koppie slopes, e.g. near Glen and is occasionally browsed. The tree *Tarchonanthus minor* is sparsely scattered on the higher slopes of koppies and hills. It is a good fodder tree and 6 to 10 feet high. The beautiful tree *T. camphoratus* var. *litakunensis* occurs in great numbers on the eastern and southern slopes of large ridges near Glen and south-west of Glen. It reaches a height of 12 feet, flowers in the middle of winter and is readily browsed by stock. *Helichrysum dregeanum* and *H. zeyheri* are common species which are 6 to 12 inches tall but fail to attain any prominence. The edible robust shrub *Pegolettia retrofracta* attains much prominence on the eastern and southern slopes near Glen. This shrub is 2 to 3 feet high and has numerous yellow flowers. *Senecio othonniformis* is a slightly succulent-leaved herb with yellow flowers and occurs in the shade of shrubs on koppies and rises. *Euryops sulcatus* var. *densifolius*, which is characteristic of the karroid koppies north of Bloemfontein, is only occasional on other stony koppies, hills and ridges in this area. It has been found on sandstone as well as on doleritic outcrops and is often associated with a sparse stand of grasses. It is not eaten except for its young flowers which are yellow and brighten up the surroundings in autumn. The encroachment of this shrub has been dealt with by Potts and Tidmarsh (1937). *Gazania jurineaefolia* is typical of Themeda veld but frequently occurs also on stony rises and gravel outcrops. It is deep rooted and has yellow or whitish flowers. *Berkheya kuntzei* is a sub-woody spinescent species with large yellow flowers.

CHAPTER 8.

GRASSVELD.

The greatest part of the area is covered by grasses which usually occupy the flats, bults, plains, vleis and edges of the valleys. Normally the grassveld is characterised by the dominance of a few grass species with a number of regularly associated forbs and bushes. As there is no indication that grassland on well rested camps on the bults, flats and vleis is succeeded by bushes or trees, grassveld is regarded as the climax vegetation on the situations mentioned. On certain places in the valleys and along watercourses, grassveld is replaced by shrubs and trees (see Chapter 6).

Most of the grasses in the area are usually frosted at the end of May or beginning of June but a gradual slowing of growth takes place from the beginning of May onwards. Little or no growth occurs from May to September. When the temperature rises deep-rooted shrubs and some of the geophytes start growing but the growth of grasses is negligible until after the first spring rains. As the first effective spring rains fall in October the growing season for veld is about from October to April, i.e. approximately 6 to 7 months.

Tidmarsh (1948) and Acocks (1953) state that the Karroo and adjacent grassveld have been the scene of great changes during the past century and that the Karroo has advanced in a northern and eastern direction at the expense of the grassveld.

The area under consideration is described by Acocks (1953) as the Central variation of the Dry-Cymbopogon-Themeda Veld, except for a small north-eastern part which falls in his Transitional Cymbopogon-Themeda Veld. Acocks's first 12 plant species of general occurrence are given below:—

Themeda triandra
Aristida congesta
Eragrostis lehmanniana
E. superba
Cynodon dactylon
Setaria flabellata
Tragus koelerioides
Elyonurus argenteus
Anthephora pubescens
Cymbopogon plurinodis
Eragrostis chloromelas
Heteropogon contortus.

The writer's observations confirm that these species are the most important of Themeda-veld of the bults and flats. Acocks's description of these veld types can therefore be considered as a brief characterisation of the grassveld as described in this thesis. The veld should be rightly called a Themeda-veld, having the tall *Cymbopogon plurinodis* as a typical associate on well managed and rested places.

Soil and water conditions are important factors in plant distribution. Sandy and sandy-loam soils are the most extensive in this area. They occur on the flats and bults and are characteristically covered by Themeda-grassveld. The heavy turfy and clayey soils are restricted to the valleys of watercourses, as well as to vleis. Their vegetation consists of the Valley Acacia Bush community (described in Chapter 6) and the Valley–Vlei Grassveld described below. Limestone soils and outcrops are scattered here and there through the central and western parts of the area and are typically covered by Kalkveld.

1. VALLEY AND VLEI GRASSVELD.

This community usually fringes the Valley Acacia Bush community in the valleys. In Chapter 1 the soils of the valleys and vleis are described as generally dark blackish-brown clays which are fairly compact when moist, otherwise cloddy to granular. They are of alluvial-colluvial origin and generally contain an appreciable amount of soluble salts. The water does not penetrate easily into these heavy soils and numerous spots occur where the grasses are replaced by drought-resistant shrubs and succulents. These spots are usually known to farmers as " brackish " spots on which perennial grasses are poorly represented and are typically replaced by karroid (Ganna) plants and ruderals (see also next page and Chapter 1). The Ganna community is discussed in Chapter 6.

In Chapter 6 the conclusion was reached that it is principally water which determines the distribution of grass, karroid and *Acacia karroo* communities along the valleys. In places where a certain amount of water accumulates without the soil's becoming water-logged, Setaria-Panicum-Themeda grassveld predominates. On water-logged places hydrophytic weeds, e.g. *Polygonum* spp. etc., occur (see Chapter 5). On higher places, especially where the soil has a high run-off so that little water penetrates into the soil the highly adapted, drought resistant, deep rooted, karroid plants predominate (Ganna-veld).

A soil sample for chemical analysis was taken on virgin soil in the valley of the Modder River, Glen. This soil consists of a dark brown clay and the sample site is situated approximately 400 yards from the Modder River. The soil is covered by grassveld consisting chiefly of *Setaria nigrirostris* with a few plants of *Salsola glabrescens* scattered here and there.

Analyses of an upper soil sample taken to a depth of one foot and a deeper sample taken to a depth of two feet were done by Mr. A. van Schalkwyk. The averages of duplicate determinations are given below. (Analysed on an oven dry basis).

Depth.	pH.	Salts p.p.m.	Percentage N. Except Nitrates.	P_2O_5 Total. Per Cent.	CaO Total. Per Cent.	Loss on Ignit. Per Cent.	Hygroscopic Moisture. Per Cent.
1 to 12 inches.....	7·07	330	0·103	0·080	0·416	5·41	3·953
12 to 24 inches.....	7·4	416	0·068	0·055	0·452	4·86	4·149

These analyses indicate that the upper soil contains a relatively high percentage of nitrogen and P_2O_5. The upper and deeper soil contain also a relatively high percentage of CaO and a reasonable quantity of salts. The soil is slightly alkaline but not brackish.

In the valley of the Modder River the Valley–Vlei Grassveld community is less extensively distributed than the Valley Acacia Bush or Ganna communities (see also Chapter 6).

Generally the vegetation of the valleys and vleis consists of predominating sweet grasses with scattered trees, shrubs and forbs in between. This grass vegetation is best developed on the wetter but well drained situations, e.g. on certain parts of the lower valley slopes, especially where protected against overgrazing.

To obtain definite data as to which species are characteristic of the Valley–Vlei Grassveld and which are the typically associated species in this community, seven botanical analyses were made using the Wheel Point method. The characterisation of this community is discussed first and is followed by a general account of the less important species occurring in this community and of those that were not encountered in the Wheel Point surveys.

(*a*) Botanical Analyses of Typical Valley–Vlei Grassveld.

A number of botanical analyses of Valley–Vlei grassveld were made in 1953. The results of these surveys are presented in Table 10. This table gives a picture of the botanical composition of Valley–Vlei grassveld occurring on heavy soils. The following is a short description of the sites on which these surveys were made:—

(1) Eight morgen of *Setaria nigrirostris* veld [plot No. A. 4 (1)], part of a large camp, No. A. 4 (see map No. 1), was surveyed on 27th April, 1953. The camp is 195 morgen in extent and is in the valley of the Modder River at the Glen College of Agriculture. The soil is a dark blackish clay into which the water seems to penetrate quite easily. The ground has a slight inclination towards the Modder River and the area surveyed lies $\frac{3}{4}$ miles south of the river. The soil on which this type of vegetation is encountered requires a high rainfall for maximum plant growth. The grasses are therefore most conspicuous and evident during seasons with a heavy rainfall.

(2) On 21st September, 1953, two separate 1-morgen plots, Nos. A. 4 (2) and A. 4 (3), in the eight morgen area surveyed on 27th April, 1953 [plot No. A. 4 (1)], were selected and surveyed. A study of these surveys shows the most common associated autumn and spring growing forbs and ruderals.

(3) A third one-morgen area No. A. 4 (4), also in camp No. A. 4, was surveyed on 22nd September, 1953. This area lies a few hundred yards to the west of the above areas. Camp No. A. 4

has been grazed for approximately the past 20 years by Africander cattle. For the past six years (1947 to 1952) it was stocked as follows:—

Year.	Rate of Stocking.	Rest Periods.
1947	One mature animal per 25 morgen.....	January to May.
1948	One mature animal per eight morgen.....	February and December.
1949	One mature animal per 16·6 morgen.....	April, May, August to November.
1950	One mature animal per 11·1 morgen.....	January and February.
1951	One mature animal per seven morgen.....	Not rested.
1952	One mature animal per 6·6 morgen.....	December.
6 years average	One mature animal per 12 morgen.....	2·7 months per annum.

It can be said that this camp was not heavily stocked but the rest periods were rather short. The areas surveyed are more or less representative of the veld found in a large part of camp No. A. 4 and also on well managed veld in the Modder River valley.

(4) Two one-morgen areas in a camp on the farm Bishop's Glen were surveyed on 23rd September, 1953. This camp lies between the Rhenostersspruit and the Modder River and is a few hundred morgen in extent. It adjoins the farm of the Glen College of Agriculture. Large vleis which are densely covered by vlei-grasses are found on the farm Bishop's Glen. The first survey (Bishop's Glen No. 1) was made on the upper, drier part of a vlei, and the second survey (No. 2) on the lower wetter part of the same vlei. Generally these vleis are well managed and are in good condition. They are usually grazed in winter and rested in summer. The soil consists of a black turf.

(5) A survey of a further vlei-like area of one morgen, situated in the valley of the Middelwaterspruit was made on 23rd September, 1953. This piece of ground lies in camp No. M. 3 of the Glen College of Agriculture (see map No. 1). The ground in the centre of the vlei, where the survey was made, consists of black clay which is densely covered by grasses. Camp No. M. 3 which is 83 morgen in extent has been grazed by sheep for approximately the past 20 years. This camp was rested rotationally and the vlei grasses are in a good condition.

In Table 10 the plants are classified according to their degree of presence. The approximate height of the plants is also given.

TABLE 10.—*Botanical Surveys of Typical Well Managed Valley–Vlei Grassveld occurring in the Valleys of the Modder River and Middelwaterspruit. Percentage Basal Cover (B.C.), Percentage of Total Vegetation (Percentage of Veg.), Degree of Presence, and approximate Height of Plants. Wheel Point Method, Lines Six Yards apart, Points 4·7 Feet apart within Lines.* 1,000 *Points per Plot.*

Plot No.	Degree Pres. out of 7.	Approximate Height.	A. 4 (1).*		A. 4 (2).		A. 4 (3).		A. 4 (4).		Bishop's Glen (1).		Bishop's Glen (2).		M. 3.	
Size of Plots.			Eight Morgen.		One Morgen.		One Morgen.		One Morgen.		One Morgen.		One Morgen.		One Morgen.	
Date of Survey.			27th April, 1953.		21st September, 1953.		21st September, 1953.		22nd September, 1953.		23rd September, 1953.		23rd September, 1953.		23rd September, 1953.	
Species.			Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.
Setaria nigrirostris.....	7	C	8·75	46·3	8·9	54·2	9·7	56·5	5·5	31·6	0·4	1·7	8·2	31·7	2·0	9·1
Eragrostis bicolor.....	7	B	1·75	9·2	2·0	12·2	1·9	11·2	7·5	43·3	0·3	1·1	12·2	47·2	2·2	10·1
Panicum stapfianum.....	7	C	2·0	10·6	1·8	10·9	2·0	11·6	0·2	1·3	12·6	46·4	1·8	6·9	0·5	2·3
Eragrostis curvula.....	6	C	0·7	3·7	0·8	4·8	0·2	1·1	—	—	5·5	20·2	0·3	1·1	1·3	6·0
Medicago denticulata†..	6	A	0·55	3·0	0·6	3·8	1·2	6·9	0·2	1·3	—	—	0·2	0·7	0·1	0·5
Themeda triandra.....	5	C	0·35	1·9	0·2	1·2	0·3	1·7	—	—	7·9	25·7	—	—	0·2	1·0
Cenia microglossa†.....	5	A	—	—	0·8	4·8	1·2	6·9	2·5	14·3	0·2	0·8	2·0	7·8	—	—
Brachiaria eruciformis†.	5	B	2·85	15·1	0·7	4·3	0·4	2·2	1·2	6·8	—	—	0·4	1·5	—	—
Chloris virgata†.....	4	B	0·3	1·6	—	—	0·1	0·6	—	—	0·1	0·4	0·2	0·7	—	—
Salsola glabrescens.....	4	C	0·25	1·3	0·2	1·2	—	—	—	—	0·1	0·4	0·1	0·4	—	—
Tragus racemosus†.....	3	A	0·15	0·8	—	—	—	—	—	—	0·2	0·8	—	—	0·3	1·4
Homeria pura†.....	3	C	0·1	0·5	0·1	0·6	—	—	—	—	—	—	—	—	0·4	1·9
Sporobolus ludwigii.....	2	B	—	—	0·2	1·2	—	—	—	—	—	—	—	—	1·0	4·6
Digitaria eriantha.....	2	C	0·15	0·8	—	—	—	—	—	—	0·5	1·7	—	—	—	—
Cyperus usitatus†.....	2	A	—	—	—	—	—	—	—	—	—	—	0·3	1·1	0·2	1·0

*2,000 Points taken, Lines 12 yards apart, Points 3·1 yards within lines. †Annuals and ruderals.
A = Plants one to three in. high; B = Plants four to 12 in. high; C = Plants more than 12 in. high.

TABLE 10.—*Botanical Surveys of Typical Well Managed Valley-Vlei Grassveld occurring in the Valleys of the Modder River and Middelwaterspruit. Percentage Basal Cover (B.C.), Percentage of Total Vegetation (Percentage of Veg.), Degree of Presence, and approximate Height of Plants. Wheel Point Method, Lines Six Yards apart, Points 4·7 Feet apart within Lines. 1,000 Points per Plot* (contd.).

Plot No.	Degree Pres. out of 7.	Approximate Height.	A. 4 (1).*		A. 4 (2).		A. 4 (3).		A. 4 (4).		Bishop's Glen (1).		Bishop's Glen (2).		M. 3.	
Size of Plots.			Eight Morgen.		One Morgen.		One Morgen.		One Morgen.		One Morgen.		One Morgen.		One Morgen.	
Date of Survey.			27th April, 1953.		21st September, 1953.		21st September, 1953.		22nd September, 1953.		23rd September, 1953.		23rd September, 1953.		23rd September, 1953.	
Species.			Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.	Percentage B. C.	Percentage Veg.
Cynodon hirsutus.....	2	A	0·15	0·8	—	—	—	—	—	—	—	—	—	—	0·3	1·4
Sporobolus fimbriatus....	2	C	0·1	0·5	—	—	0·1	0·6	—	—	—	—	—	—	—	—
Pennisetum sphacelatum..	1	C	—	—	—	—	—	—	—	—	—	—	—	—	8·3	38·4
Eragrostis plana.....	1	C	—	—	—	—	—	—	—	—	—	—	—	—	1·0	4·6
Cyperus marginatus.....	1	C	—	—	—	—	—	—	—	—	—	—	—	—	0·5	2·3
Acalypha segetalis†.....	1	B	0·25	0·8	—	—	—	—	—	—	—	—	—	—	—	—
Eragrostis obtusa.....	1	B	0·20	1·0	—	—	—	—	—	—	—	—	—	—	—	—
Andropogon appendiculatus	1	C	—	—	—	—	—	—	—	—	—	—	—	—	3·1	14·4
Total of species each constituting less than one per cent of Total Veg..	1	—	0·30	1·6	0·1	0·6	0·1	0·6	0·2	1·3	0·2	0·8	0·2	0·7	0·2	1·0
TOTAL.....			18·9	99·5	16·4	99·8	17·2	99·9	17·3	99·9	27·1	100	25·9	99·8	21·6	100
NUMBER OF SPECIES...			16		11		10		6		10		10		15	

*2,000 Points taken, Lines 12 yards apart, Points 3·1 yards within lines. †Annuals and ruderals.
A = Plants one to three in. high; B = Plants four to 12 in. high; C = Plants more than 12 in. high.

1. *Plot No.* A. 4 (1).

This 8-morgen plot which includes the 1-morgen plots Nos. A. 4 (2) and A. 4 (3), has a total plant cover of 18·9 per cent. The dominant species is *Setaria nigrirostris* which constitutes 46 per cent of the total plant cover. Perennial grasses constitute 75 per cent of the total basal cover and more than half of this consists of *Setaria nigrirostris*. The perennial grasses most typically associated with *Setaria nigrirostris* are: *Panicum stapfianum*, *Eragrostis bicolor* and *E. curvula*. These grasses represent 10·6, 9·2 and 3·7 per cent, respectively, of the total vegetation.

Dense stands of annual pioneers occur on open situations between the grass tufts. *Brachiaria eruciformis* is abundant and constitutes 15 per cent of the total vegetal cover. When the survey was made this grass was in a late seed stage and numerous small prostrate plants of *Medicago denticulata* were visible. Shrubs and perennial herbs play an unimportant role and constitute only 1·58 per cent of the total vegetation. Of these *Salsola glabrescens* is the most abundant and represents 1·32 per cent of the total plant cover. As no seedlings or plants of *Cenia microglossa* were established as yet, no plants of this species were found during the survey on 27th April, 1953. Almost all the plants are palatable, except for a few annuals like the poisonous *Homeria pura*, *Tribulus terrestris* and the annual legume *Crotalaria globifera* which causes "stywesiekte" in cattle. The above-named plants constitute only 1·3 per cent of the total vegetation.

2. *Plot No.* A. 4 (2).

Setaria nigrirostris is dominant and constitutes 54 per cent of the total cover. *Eragrostis bicolor*, *Panicum stapfianum* and *Eragrostis curvula* are the most common associated grasses. Annual pioneers and ruderals occur on open spots between the perennial grass tufts. The winter-growing *Cenia microglossa* and *Medicago denticulata* are the most common associated forbs. *Brachiaria eruciformis* is the commonest of the summer growing annual grasses. This plot has a total cover of 16·4 per cent.

3. *Plot No.* A. 4 (3).

Setaria nigrirostris is dominant and constitutes 56 per cent of the total cover. The most abundant associated perennial grasses are *Panicum stapfianum* and *Eragrostis bicolor*. *Medicago denticulata*, *Cenia microglossa* and *Brachiaria eruciformis* are the most common associated annuals. *Eragrostis curvula* occurs but constitutes only 1·1 per cent of the total cover. This plot has a total plant cover of 17·2 per cent.

The 8-morgen plot No. A. 4 (1) includes the two 1-morgen plots Nos. A. 4 (2) and A. 4 (3) and if the vegetation of these plots is compared the following points are evident (see Table 10):—

(*a*) The total basal cover of the 8-morgen plot is a little higher than that of the 1-morgen plots. The basal cover of plot No. A 4 (2) is the lowest (16·4 per cent).

(*b*) *Setaria nigrirostris* is dominant in all three plots, *Eragrostis bicolor* and *Panicum stapfianum* are typical associated species. The percentage basal cover of almost all these species is a little lower on the 8-morgen than on the 1-morgen plots. *Medicago denticulata* and *Brachiaria eruciformis* are the most typical associated annual plants; the latter was the most abundant in April on plot No. A. 4 (1).

(*c*) A total of 20 species was recorded from the 8-morgen plot and only 12 from plot No. A. 4 (2) and 11 from plot No. A. 4 (3). Eight species are constantly present in all the three plots analysed. On plots Nos. A. 4 (2) and A. 4 (3), jointly two morgen, 15 species were found. Normally there are more species on larger than on smaller areas.

(*d*) With the survey on 21st September, 1953, plants of *Cenia microglossa* [constituting 4·8 and 6·9 per cent of the total vegetation on plots Nos. A. 4 (2) and A. 4 (3) respectively] were recorded on the 1-morgen plots.

4. *Plot No.* A. 4 (4).

This area has a total cover of 17·3 per cent. *Eragrostis bicolor* and *Setaria nigrirostris* are co-dominant. The winter growing *Cenia microglossa* and the summer growing *Brachiaria eruciformis*, both ruderals, are the most common associated species. This stand is very poor in species, only seven were found (see Table 10).

5. *Bishop's Glen No.* 1.

This plot has a total cover of 27·1 per cent which is the highest obtained in all surveys made in the present study. *Panicum stapfianum* is dominant and constitutes 46 per cent of the total basal cover. The most abundant associated perennial grasses are *Themeda triandra* and *Eragrostis curvula*. *Setaria nigrirostris* and *Eragrostis bicolor* together constitute only 2·8 per cent of the total basal cover. The common annuals and pioneers are present in very small numbers and constitute only 2 per cent of the total basal cover. As a result of the high basal cover of perennial grasses there is a little space for pioneers and ruderals.

6. *Bishop's Glen No.* 2.

From Table 10 it can be seen that this plot has a high basal cover, i.e. 25·9 per cent. *Eragrostis bicolor* is dominant and constitutes 47 per cent of the total basal cover. *Setaria nigrirostris* is co-dominant (31·7 per cent of the total basal cover) and *Panicum stapfianum* is the most abundant associated perennial grass constituting 6·9 per cent of the total cover. The winter growing pioneer *Cenia microglossa* is common on the bare spaces between the grass tufts. Ruderal grasses are unimportant.

7. *Plot No.* M. 3.

This plot has a total basal cover of 21·6 per cent and is different from the other plots in that the strongly tufted *Pennisetum sphacelatum* is dominant, constituting 38·4 per cent of the total cover. *Andropogon appendiculatus*, *Eragrostis bicolor* and *Setaria nigrirostris* are the most common associated species with 14·4, 10·1 and 9·1 per cent of the total basal cover. *Eragrostis curvula* and *Sporobolus ludwigii* occupy 6 and 4·6 per cent of the total cover. Ruderals and pioneers are unimportant; the poisonous *Homeria pura* is the most common.

(*b*) General Characterisation of the Valley–Vlei Grassveld Community.

The following conclusions can be drawn from Table 10.

(1) The Valley–Vlei Grassveld has, on the well managed places investigated, a total basal cover varying from 16·4 to 27·1 per cent. Normally a 25 per cent cover can be regarded as a dense stand. Themeda-veld may attain as dense a cover, especially where the veld is judiciously utilized (see Table 13). On well managed and moister places the Valley–Vlei Grassveld community may exceed 25 per cent basal cover.

(2) The Valley–Vlei Grassveld is characterised by the dominance of perennial grasses. The surveys of the seven plots show that *Setaria nigrirostris*, *Eragrostis bicolor* and *Panicum stapfianum* are constantly present. On three plots, i.e. Nos. A. 4 (1), A. 4 (2) and A. 4 (3), *Setaria nigrirostris* dominates; on two plots, No. A. 4 (4) and Bishop's Glen No. 2, *Eragrostis bicolor* dominates with *Setaria nigrirostris* as a co-dominant. In plot No. 1 on Bishop's Glen *Panicum stapfianum* dominates and in the plot in camp No. M. 3 *Pennisetum sphacelatum*. The latter grass was, however, not encountered in any of the other plots surveyed.

Eragrostis curvula and *Themeda triandra* are typically associated with the dominant grasses. (Degree of presence 6 and 5, respectively). Both species usually cover less than 2 per cent of the area. In one stand (Bishop's Glen No. 1) however, they are more abundant and reach a basal cover of 5·5 and 7 per cent respectively.

Medicago denticulata, *Cenia microglossa* and *Brachiaria eruciformis* (the two last species are characteristic for vleis) are more or less constantly associated with the grasses mentioned. (Degree of presence 6, 5 and 5 respectively). These annuals are usually confined to open, bare situations and may constitute up to 15 per cent of the total vegetation.

The ruderal grasses *Chloris virgata* and *Tragus racemosus* and the tulp *Homeria pura* are often in this community. (Degree of presence 4, 3 and 3 respectively). These species occur on open spots and, if present, are uncommon. *Salsola glabrescens* is often on the driest spots in this grassveld and never constitutes more than 2 per cent of the total vegetal cover. *Sporobolus ludwigii*, *S. finibriatus*, *Digitaria eriantha*, *Cyperus usitatus* and *Cynodon hirsutus* are found in the Valley–Vlei Grassveld and, if present, are uncommon (see Table 10).

The six last species in Table 10 are rare in this community (degree of presence 1).

From the species composition it can be concluded that plots Nos. A. 4 (1), A. 4 (2), A. 4 (3) A. 4 (4) and Bishop's Glen No. 2 are the most typical examples of the Valley–Vlei Grassveld community. In all these plots the two important Valley–Vlei grasses, *Setaria nigrirostris* and *Eragrostis bicolor* are predominant. Two variations of this community are, however, found, i.e. in plots Nos. A. 4 (1), A. 4 (2) and A. 4 (3) where *Setaria nigrirostris* dominates with *Eragrostis bicolor* as a sub-dominant and in the other plots Nos. A. 4 (4) and Bishop's Glen No. 2 where *Eragrostis bicolor* dominates with *Setaria nigrirostris* as the sub-dominant (see Table 10). Two more extreme variations of the Valley–Vlei Grassveld community

are represented by plot No. 1 on Bishop's Glen and the plot in camp M. 3. The first plot represents a drier variation of this grassveld community in which *Panicum stapfianum* dominates with *Themeda triandra* and *Eragrostis curvula* as sub-dominates (see Table 10). The plot in camp No. M. 3 represents, on the other hand, the moister variation of this community. In the moister valley of the Middelwaterspruit in camp No. M. 3 the rather hygrophilous *Pennisetum sphacelatum* and *Andropogon appendiculatus* are dominant and sub-dominant respectively. *Setaria nigrirostris* and *Eragrostis bicolor* both constitute less than 11 per cent of the total vegetation. The hygrophilous *Eragrostis plana* and *Cyperus marginatus* represent 4·6 and 2·3 per cent, respectively, of the total vegetation on this plot and were not found in any of the other stands examined.

(*c*) Botanical Analysis of an Overgrazed Spruit Camp.

The deleterious effects of continuous overgrazing in South Africa have been stressed on numerous occasions by various agricultural research workers (e.g. Morris 1944, Preller 1950, Acocks 1953).

Acocks discusses the instability of the vegetation of South Africa and concludes that as a result of richer soils and better water conditions the more palatable plants are usually found in the valleys and depressions. The consequence is that grazing animals concentrate on these situations and may cause soil erosion. He states further that over grazing is conspicuous n the Dry Cymbopogon-Themeda veld of the Orange Free State.

The Middelwaterspruit Camp, Mx. a.

A botanical survey of a 30-morgen camp in the valley of the Middelwaterspruit, Glen, was made in April, 1952. This camp, Mx. a, is situated on both sides of the spruit and is approximately 800 yards long by 400 yards wide with the spruit running more or less lengthwise through it. The soil of this camp is a dark-brown loam which seems to have a fairly good drainage. On the banks of this spruit and on low-lying spots the soil is heavier than on the edges of the camp. The ground has a slight inclination towards the spruit. On both sides of this camp large, almost level plains occur which are covered, except on disturbed and overgrazed places, by Themeda-grassveld. This survey was made with the Wheel Point apparatus and with the exception of a dense *Acacia karroo* community, approximately 20 to 50 yards wide on both sides of the spruit, the whole camp was surveyed. Associated with *A. karroo* are *Asparagus rivalis*, *Ziziphus mucronata*, *Rhus pyroides* and *R. ciliata*.

This spruit camp has in the past been heavily stocked by small stock and cattle. It has been more or less continuously grazed for the past 20 years or more. Dense stands of Themeda occur on adjacent well rested camps and at roadsides, and it is probable (if the veld had been properly rested) that Themeda would have predominated on the higher sides of this camp and Valley–Vlei grasses on the banks and wetter spots as has been described in section (*b*) of this chapter. In this camp *Setaria nigrirostris*, *Panicum stapfianum* and *Eragrostis bicolor* have probably been destroyed and are now restricted to a very few tufts in a few depressions adjoining the spruit. The Themeda-veld which is on the outer and higher edges of this camp has also degenerated to a pioneer stage.

Similar overgrazing is common on farms in this area.

The survey was made after the camp had been rested for a year and when the grasses were in seed. Results are given in Table 11.

TABLE 11.—*Botanical Survey of a* 30 *morgen heavily grazed Camp in the Valley of the Middelwaterspruit, Glen*: 4,000 *points taken*; *Wheel Point Method. Lines* 12 *Yards apart, Points* 3·14 *Yards apart within Lines. April*, 1952.

Plant Species.	Percentage Basal Cover.	Percentage of Total Vegetation.
1. *ARISTIDA CONGESTA* AND ANNUALS.		
Aristida congesta and *A. curvata**	**2·55**	15·74
Tragus racemosus	0·50	3·09
Berkheya epitrachys	0·075	0·46
Alternanthera repens	0·025	0·15
Tribulus terrestris	0·025	0·15
Urochloa panicoides	0·025	0·16
TOTAL	3·20	19·75
2. *PERENNIAL* GRASSES.		
Cynodon dactylon and *C. hirsutus**	**4·625**	28·54
Themeda triandra	2·20	13·58
Eragrostis obtusa	1·250	7·71
Eragrostis lehmanniana	0·675	4·17
Tragus koelerioides	0·575	3·55
Eragrostis curvula	0·450	2·78
Enneapogon scoparius	0·375	2·31
Eragrostis plana	0·10	0·62
Sporobolus fimbriatus	0·10	0·62
Aristida vestita	0·050	0·31
Digitaria eriantha	0·050	0·31
Heteropogon contortus	0·050	0·31
Cymbopogon plurinodis	0·025	0·15
Echinochloa holubii	0·025	0·16
Fingerhuthia africana	0·025	0·15
Setaria flabellata	0·025	0·16
TOTAL	10·60	65·43
3. SHRUBS, BUSHES AND PERENNIAL HERBS.		
(*a*) EDIBLE.		
Nenax microphylla	**0·350**	2·16
Aster muricatus	0·100	0·61
Hermannia depressa	0·100	0·62
Indigofera alternans	0·075	0·46
Salsola glabrescens	0·075	0·47
Acacia karroo (small)	0·025	0·15
TOTAL	0·725	4·47

* At the time of survey these species could not easily be distinguished apart.

TABLE 11.—*Botanical Survey of a 30 morgen heavily grazed Camp in the Valley of the Middelwaterspruit, Glen: 4,000 points taken; Wheel Point Method. Lines 12 Yards apart, Points 3·14 Yards apart within Lines. April, 1952* (contd.).

Plant Species.	Percentage Basal Cover.	Percentage of Total Vegetation.
(*b*) OF LITTLE GRAZING VALUE.		
Pentzia globosa	**0·300**	1·85
Lycium oxycladum	0·275	1·70
Aptosimum depressum	0·150	0·92
Chrysocoma tenuifolia	0·150	0·93
Nestlera conferta	0·125	0·77
Rhus ciliata	0·125	0·77
Othonna pallens	0·100	0·62
Cyperus usitatus	0·075	0·46
Salvia clandestina var. *angustifolia*	0·075	0·46
Hibiscus trionum	0·050	0·31
Seddera capensis	0·050	0·31
Barleria macrostegia	0·025	0·15
Blepharis integrifolia	0·025	0·15
Convolvulus dregeanus	0·025	0·16
Dicoma macrocephala	0·025	0·16
Geigeria africana	0·025	0·15
Solanum panduraeforme	0·025	0·15
Stachys hyssopoides	0·025	0·16
Walafrida saxatilis	0·025	0·16
TOTAL	1·675	10·34
GRAND TOTAL	16·20	99·99

* At the time of survey these species could not easily be distinguished apart.

A dense stand of Acacia karroo occurs on the banks of the spruit (approximately 20 to 50 yards wide on both sides) which could not be surveyed by this method.

The plants in Table 11 are classified principally according to their life span, grazing value and abundance. The following should be noted:—

(1) In the camp as a whole the soil and vegetation are rather heterogeneous. The vegetation is not distinctly zoned but shows a gradual transition from Vlei-grassveld to Themeda-bultveld. If the camp had been rested longer a more distinct zonation might have appeared. A comparison of the basal cover, etc., of this camp with that of other camps is, therefore, of limited value only. The total cover of this camp is lower than that of most, but equal to some, of the well managed Valley–Vlei grassveld plots (see Table 10). It is lower than that of well managed Themeda-veld and Kalkveld (see Tables 14 and 25). The last camps are approximately 500 yards from the Middelwaterspruit camp.

(2) The vegetation of this spruit-valley camp is in a stage of retrogression. A comparison of the total basal cover of annual pioneer plants of this camp with that of the well managed Valley–Vlei grassveld plots (see Tables 10 and 11) is presented in Table 12.

TABLE 12.—*Vegetal Cover of Eight Valley–Vlei Grassveld Plots.*

Camp No.	Annuals: Percentage of Total Basal Cover.	Percentage Total Basal Cover.	Classification.
A. 4 (4)	22·4	17·3	C
A. 4 (1)	21·8	18·9	C
Middelwaterspruit	19·75	16·2	D
A. 4 (3)	16·6	17·2	C
A. 4 (2)	13·5	16·4	C
Bishop's Glen No. 2	11·8	25·9	A
M. 3	4·8	21·6	B
Bishop's Glen No. 1	2·0	27·1	A

The veld on the above-named plots has been classified into four groups (A to D), based principally on the general condition of the veld. From the above figures it is clear that the total cover of veld which is regarded as being in an excellent condition (A), and in a good condition (B), is higher than that of veld which is in a reasonably good condition (C), and an overgrazed condition (D). Annual plants are uncommon on the plots on Bishop's Glen which are in an excellent condition (A), and on No. M. 3 which is in a good condition (B). On the plots which are in a reasonably good condition (C) and in the overgrazed camp (D) the annuals are much commoner. In the overgrazed Middelwaterspruit camp *Aristida congesta* and *A. curvata* are the most common pioneers and together constitute 15·74 per cent of the total cover (see Table 11). These species, if they occur at all, constitute less than 1 per cent of the total cover in the well managed Valley–Vlei grassveld camps where *Medicago denticulata*, *Cenia microglossa* and *Brachiaria eruciformis* are the most abundant annual plants (see Table 10).

Aristida curvata and *A. congesta* are usually indicators of overgrazing and are of little grazing value. They are often more abundant on the lighter than on heavier soils and are most common on the edges of this overgrazed spruit camp. On heavier soils *Cynodon* spp. and *Eragrostis obtusa* usually are more abundant.

A. congesta and *A. curvata*, which have sharp-pointed seeds, are a menace to sheep farmers, and are most common on camps overgrazed by sheep. The cover of annuals in the Middelwaterspruit camp, if compared with that of the adjacent well managed Themeda-veld and Kalkveld (see Tables 14 and 25), is significantly higher.

(3) Perennial grasses constitute 65·4 per cent of the total cover of this camp. The most characteristic valley climax grasses like *Setaria nigrirostris* and *Panicum stapfianum* (as well as Themeda which may be characteristic for drier valleys) have totally or largely been destroyed and constitute only 13·5 per cent of the total cover. A few small tufts of *Setaria nigrirostris* and *Panicum stapfianum* were observed but were not struck by the Wheel Point apparatus. The pioneers *Cynodon dactylon* and *C. hirsutus*

dominate and are followed by *Eragrostis obtusa*, which is usually regarded as a sub-climax grass. The two *Cynodon* spp. constitute 28·54 per cent and *E. obtusa* 7·71 per cent of the total cover. These pioneers are, however, seldom found in well managed Valley–Vlei grassveld (see Table 10).

(4) Edible shrubs and bushes constitute only 4·47 per cent of the total vegetation. Of these *Nenax microphylla* is the most abundant, as in other veld types.

(5) Shrubs and perennial herbs which are of little grazing value, or inedible, are better represented, with a basal cover of 1·675 per cent or 10·34 per cent of the total cover. *Pentzia globosa* and the encroaching *Lycium oxycladum* are the most common. With continuous grazing the valuable climax grasses are replaced by annuals and pioneers, and edible shrubs by inedible species.

(6) A comparison of this overgrazed valley spruit camp with an adjoining more or less similarly treated Themeda-camp (see Table 14) shows the following:—

(*a*) *Echinochloa holubii*, *Eragrostis plana*, *E. curvula*, *Salsola glabrescens* and young plants of *Acacia karroo* are typically encountered in the Valley–Vlei grassveld and, although they are uncommon in the overgrazed Middelwaterspruit camp, they are almost or totally absent from Themeda veld. Tufts of typical valley grasses, e.g. *Setaria nigrirostris* and *Panicum stapfianum* were seen on the low-lying situations in the spruit camp. These species, are, however, absent from Themeda veld (see Tables 13 and 14).

(*b*) On the overgrazed spruit camp *Cynodon dactylon* and the pioneer *Aristida* spp. dominate. *A. congesta* and *Tragus koelerioides* are the most abundant pioneer species in the overgrazed Themeda camp.

As a result of overgrazing the characteristic climax grasses of both Themeda- and Valley–Vlei grassveld are destroyed and replaced by pioneers and annuals like *Cynodon dactylon* and *Aristida congesta*.

(*d*) Notes on the More Important Grass Species.

Setaria nigrirostris is common on heavy soils along watercourses. At the Glen College of Agriculture many morgen of this grass occur in the Modder River valley. It is most conspicuous and best developed during summer seasons with a high rainfall. It reaches a height of from 3 to 4 feet and is usually so dense that practically no other species is visible (see photo 14). *S. nigrirostris* is very palatable to all types of stock. It produces a big crop of large and heavy caryopses which are much eaten by birds. Although this grass is strongly rooted and tufted it is often destroyed by overgrazing. Other Setaria species, like *S. imberbis*, were not recorded in the plots surveyed but may occur in the valleys and vleis.

Panicum stapfianum is also palatable and provides good winter grazing. It also is often destroyed by overgrazing. *P. coloratum* and *P. deustum* were not encountered in the plots surveyed but are occasional in the vleis and valleys.

Pennisetum sphacelatum forms large tufts and although palatable to cattle it is too fibrous for sheep when overgrown. It is usually in the beds of watercourses and vleis but is rather rare. *Sporobolus ludwigii* and *Eragrostis bicolor* are widely scattered in the valleys and vleis. Both are small, tufted grasses and although valuable as grazing for sheep they are often too short for cattle. *Eragrostis curvula* is a valuable grazing grass. *E. nebulosa* and *E. micrantha* are only occasionally found in vleis and on disturbed sites. *E. chloromelas* and *E. obtusa* are usually on over-grazed bult and valley camps.

Digitaria eriantha is widely scattered on the flats and bults but seems to be quite at home in wetter places on the bults and on heavy soils in the vleis and valleys, where it is usually taller and leafier.

Brachiaria eruciformis is a characteristic annual pioneer on heavy soils, especially in the valley of the Modder River. It is only conspicuous in sparse vegetation. This summer grass is liked by stock and for a few months after summer rains it affords good grazing. It is often a weed on heavy, irrigated soils.

The common pioneer grasses *Cynodon dactylon* and *C. hirsutus* are common on overgrazed and bare places in the valleys and vleis (see Table 11). They are not only valuable in colonizing and binding bare erodable soils but afford valuable sweet grazing.

The ruderals *Chloris virgata* and *Tragus racemosus* are abundant on bare soils in the vleis and valleys (see Table 10). They appear soon after the first summer rains and are of little grazing value. Generally they are most conspicuous on bare and overgrazed places.

As has been indicated Themeda often occurs in the vleis and valleys. Generally it is restricted to the drier places on the edges of vleis and depressions. Under moister conditions Themeda, as well as *Digitaria eriantha*, is often replaced by more hygrophilous species, e.g. *Panicum stapfianum*, *Setaria nigrirostris* and *Andropogon appendiculatus*. Where still more water collects typical hygrophilous species like *Eragrostis plana* and *Diplachne fusca* predominate.

Themeda is usually more robust in the vleis and valleys than on the bults and has a higher carrying capacity.

(*e*) Notes on the Most Common Associated Forbs, Herbs and Shrubs.

In sections 1 (*b*) and 1 (*c*) of this chapter a number of species which constitute the Valley–Vlei grassveld community have been discussed. In the account below many of the forbs, shrubs and herbs which have been found in this community are dealt with.

Juncaceae.

Juncus arabicus is a hardy uncommon rush occurring gregariously in dry vleis and on the higher banks of spruits. It forms dense patches, has leaves with sharp points and is not eaten by stock.

Liliiflorae.

Numerous species discussed in Chapter 6 are found on open situations in the grassveld, in vleis and valleys, but are not of great significance. The small bright yellow-flowered *Eriospermum corymbosum* appears just after the first spring rains in great numbers on open patches between the

grasses. Although it is frequent in the valleys and occurs also on the bults and flats, it was never found on the hills, ridges and koppies. The slender erect herb *Drimia ciliaris* forms dense clans in open grassveld on heavy soil. *Dipcadi viride* and *Eucomis undulata* are both common but not eaten by stock. The former is a common pioneer on bare spots in the valleys and the latter is gregarious between grasses—often in a rather dense grass cover. *Neobakeria comata* is very rare, only a few plants were found between *Setaria nigrirostris* tufts in the Modder River valley, Glen. *Haemanthus amarylloides* is very common in the Modder River valley and forms dense patches between the grasses (see also photo 1). The plants are inedible. The flowers are white and the leaves appear after flowering. *Moraea* spp., especially the blue flowered *M. polystachya*, and *Homeria* spp., especially the yellow-flowered *H. pura*, are typical species of the valleys, vleis, etc.

Chenopodiaceae.

Many species are widely scattered on heavy soils along the watercourses, and grow on " brackish " soils in the Modder River valley where no other plants seem to thrive. This family includes a number of pioneers which are important in colonizing bare and erodable soils. The erect winter annual *Chenopodium album* is common between the grasses in heavily grazed camps. *C. foetidum*, *C. glaucum* and *C. mucronatum* are less common pioneers restricted to heavy soils in the valleys. These pioneers are drought and frost resistant but not eaten by stock. The indigenous *Atriplex erosa* and *A. suberecta* and the alien *A. semibaccata* are characteristic pioneers in the valleys. They are evergreen, good soil protectors and readily eaten by stock, especially during winter and drought. The robust pioneer *Salsola kali* is quite common, and abundant on disturbed and overgrazed valley-camps. Although regarded as a pioneer of no value it is eaten by stock when young and is valuable in colonizing bare soils. Where the Valley-grasses do not form a dense cover a sparse stand of the local gannas *Salsola glabrescens* and *S. nigrescens* is found.

Nyctaginaceae.

The trailing magenta-flowered herb *Commicarpus pentandra* is frequent on open patches in this grassveld.

Aizoaceae.

The prolifically flowering biennial succulent *Delosperma mahoni* and *Hypertelis verrucosa* are commonly encountered on overgrazed and open patches between the grasses.

Cruciferae.

Brassica pachypoda is frequent as a pioneer between the grasses.

Leguminosae.

The small prostrate herb *Lotononis leobordea*, the annual erect herb *Crotalaria distans* and the prostrate annual *Medicago denticulata* are the most common and charateristic species occuring on heavy soils. The first species is particularly well represented on bare spots between the grasses and the second occurs on overgrazed places and where the soil has been disturbed. *M. denticulata* is locally well known as " burr-clover ". It is very conspicuous during winters which are preceded by good autumn rains. It is well grazed in spring but its burrs stick to the wool of sheep. The prostrate purple-blue flowered *Psoralea obtusifolia* forms occasional dense patches between the grasses. It is well grazed by stock.

Euphorbiaceae.

The erect herbs *Phyllanthus maderaspatensis*, *Acalypha segetalis* and the prostrate annuals *Euphorbia prostrata* and *E. inaequilatera* are pioneers found on open and eroded patches. The two last species are common weeds in gardens and lands.

Malvales.

The perennial yellow-flowered prostrate herb *Corchorus asplenifolius* and the erect herb *Hibiscus trionum* are occasional on bare spots in the Valley–Vlei grassveld where the large cream flowers of the latter species are conspicuous. Several species of *Hermannia* are frequent in the valleys and vleis. The erect shrub *H. linearifolia* and the small perennial herb *H. erodioides* are the most common.

Asclepiadaceae.

A number of species occur in the valleys with the grasses. The small herb *Schizoglossum eustegioides*, *Asclepias meyeriana* and the erect herbaceous *Xysmalobium undulatum* have been discussed in chapter 5. *Brachystelma foetidum* is a perennial herb with a tuberous root and dark brown flowers with a carrion-like odour, and occurs sparsely in local vlei-veld. *B. galpini* is rather rare.

Convolvulaceae.

Several species of *Convolvulus* occur in the Valley–Vlei grassveld community. The commonest are *Convolvulus dregeanus*, *C. sagittatus* and *C. ulosepalus*, which are deeply rooted and usually have long trailing stems. Several forms of *C. ulosepalus* have been collected, some of which are robust, and long climbing stems reaching 12 feet in height have been encountered. *C. dregeanus* is frequent in the valleys of local spruits. The genus *Ipomoea* is represented by the large magenta-flowered shrublet *I. oenotheroides*, the prostrate, large pink-flowered *I. oblongata* and the twining inconspicuously flowered *I. obscura*. The leaves of these plants are eaten by stock during periods of scarcity. *Seddera capensis*, a prostrate perennial herb, is abundant on bare situations in the valleys. It has white-creamish flowers and is valuable as a pioneer.

Labiatae.

The pinkish-flowered perennial herb *Stachys hyssopoides* occurs gregariously in vleis and spruits. *Salvia clandestina* var. *angustifolia*, an aromatic herb, *S. rugosa* and *S. runcinata* are beautiful blue-flowered species occurring as pioneers on bare spots in the valleys. They are not eaten by stock but are valuable in colonizing erodable soils.

Scrophulariaceae.

A few species are regularly encountered in the Valley–Vlei grassveld community. The prostrate sub-herbaceus *Aptosimum depressum* and *A. depressum* var. *elongatum* are found in dense mats between the grass tufts, especially on loamy and heavy soils. They have showy violet flowers, and are valuable soil colonizers but of little grazing value. The root parasites *Striga bilabiata* and *Alectra orobanchoides* are associated with this grassveld but are very rare.

Cucurbitaceae.

Kedrostis africana and *K. punctulata* are scattered in the Valley–Vlei grassveld.

Campanulaceae.

Wahlenbergia arenaria, *W. undulata* and *Lobelia dregeana* are occasionally found in the Vlei-grassveld, especially on moister spots.

Compositae.

This family is well represented in this grassveld. The following are common in the valleys and vleis: *Aster muricatus*, a small bluish-flowered shrublet, is abundantly scattered on many soil types but is most common on heavy soils in the valleys (see also Chapter 6). It favours open spots between the grasses and other shrubs and often occurs in dense patches. It is one of the best fodder shrublets in this area. Its numerous blue flowers make a pretty sight when in bloom after rains, usually during the summer and autumn. Several pioneer species of *Nidorella* grow on heavy soils. *N. resedaefolia* is the commonest and is often dominant on disturbed soils and overgrazed camps. It made a beautiful sight in November, 1950, after heavy rains when many morgen of open grassveld in the valley of the Middelwaterspruit, Glen, were covered with this yellow-flowered herb. It was inconspicuous from 1951 to 1954. Its young leaves and flowering heads are grazed by stock. *Epaltes alata* is a dry looking poisonous shrub, 6 to 18 inches high, which is common on bare patches between the grasses in the valleys, especially towards the western part of the area studied. A few species of *Helichrysum*, especially *H. pentzioides*, occur on open sites in this grassveld community. This species is common in overgrazed spruit camps especially towards the western part of the area. It has creamy flowers, is drought and frost resistant and is occasionally grazed.

A few species of *Cotula* are common inedible winter pioneers favouring open spots in the valleys and vleis. The yellow-flowered herb *Cenia microglossa* is abundant in open valley grassveld and has already been referred to in Chapters 5 and 6. Species of *Cineraria*, especially *C. lyrata*, are common under moist conditions. The genus Senecio, of which many species are toxic, is common in this grassveld community. *S. laevigatus* and *S. burchellii* are the most abundant pioneers. *Osteospermum spinescens* is a hardy yellow-flowered shrub and forms sparse stands on brackish soils in the valley of the Rhenosterspruit where the grasses are scarce. The acaulescent herb *Platycarpha parvifolia* forms dense patches in the vleis and depressions. *Tolpis capense* is scattered here and there on open spots between the grasses in the Modder River valley. The grasslike herb *Tragopogon porrifolius* favours wet vleis and lands but is not very abundant. The following weeds and ruderals are frequent in disturbed and overgrazed valleys and vleis: *Xanthium spinosum*, *Zinnia multiflora*, *Galinsoga parviflora*, *Tagetes minuta* and *Sonchus oleraceus*.

2. THEMEDA VELD ON THE FLATS, BULTS AND PLAINS.

(*a*) General Characteristics.

The Themeda grassveld is the most extensive and probably the most important plant community. About 70 per cent of the area consists of flats, bults and plains dominated by grasses, which form a waving sheet 1 to 2½ feet high in summer after good rains. During rainy summers it appears as if the grasses are very densely tufted, and that a high basal cover might be expected, but botanical analysis done with Tidmarsh and Havenga's Wheel Point method reveals that the basal cover seldom exceeds 25 per cent. In winter and during droughts the grass cover is much shorter so that the associated shrubs and herbs and the bare spaces are more conspicuous.

(1) *Notes on Themeda triandra.*

On typical well managed and rested flats and bults, *Themeda triandra* is predominant and constitutes anything up to 90 per cent of the total basal cover (see Table 13). Here it grows to 18 inches and is quite leafy but not as robust as in the valleys, vleis and flushes.

As this area was, and still is, heavily grazed by cattle and sheep, the predominating Themeda has been destroyed in many places. The best stands of Themeda occur on undisturbed places, e.g. on the unploughed edges of cultivated lands which are usually rested in summer and grazed in winter, on protected roadsides and in camps far from drinking points. Between Karree and Brandfort beautiful stands of Themeda can still be seen. From observations and botanical analyses it is clear that Themeda was, and should be, the dominant grass in this area. On overgrazed camps Themeda is replaced by more xerophytic sub-climax and pioneer grasses but can be restored by reseeding and judicious veld management.

Two forms of *Themeda triandra* occur in the area studied. A short glaucous form is mainly on the slopes of rises and stony bults, but is rare. As it leaves retain their colour through the winter it is generally regarded as good winter grazing. The second form has broad green leaves changing to a copper or reddish-brown colour in early winter. It is very common in this area and predominates on the flats and plains. It occurs also on the randjies where it is more abundant than the glaucous form. As it is much leafier it affords better summer grazing than does the glaucous-leaved form.

Both these forms of *Themeda triandra* apparently afford good winter grazing and should, therefore, be classified as " sweet " grasses. The term " sourveld " is not used in this area although, in general, the veld on the heavier soils is better for winter grazing than that on the sandy loam soils of the flats and bults.

In her cytotaxonomic studies of the species *Themeda triandra*, Gluckman (1951), distinguishes four varieties but it was not possible to determine which of them occurs in the area studied.

(2) *Soil Conditions.*

Soil samples of typical and deep sandy loam were taken from camp No. F. 1, Glen, and were analysed by Mr. H. van Schalkwyk. This camp is a flat bult densely covered by Themeda. The samples were taken to a depth of 1 foot and 2 feet, respectively. The results shown are the averages of duplicate analyses. Except for the Loss on Ignition which was based on oven dry soil, the analyses were done on air dry samples:—

Depth.	pH.	Salts pp. m.	Percentage N.	Total Percentage CaO.	Total Percentage P_2O_5.	Loss on Ignition.	Percentage Hygroscopic Moisture.
1 to 12 in.	6·15	40	0·036	0·074	0·028	2·41	1·245
12 to 24 in.	6·3	65	0·043	0·082	0·032	2·98	1·542

Obviously this soil is not rich in nitrogen, P_2O_5 and CaO. There is also little difference in the analyses of the first and second feet of soil. The pH is little lower than the neutral point.

On lighter sandy soils occurring in this area towards the west, *Anthephora pubescens* and *Eragrostis* spp. come in strongly and are often more abundant than Themeda. Towards the east the percentage cover of *Cymbopogon plurinodis* and *Digitaria* spp. increases. It is not possible to say whether this is due to differences in soil conditions (texture and fertility) or to the decreasing rainfall towards the west.

(*b*) The Species Composition of Themeda-veld.

Pure stands of Themeda give the impression that the tufts are massed so closely that little unoccupied ground is available for other grass species and forbs, but on a closer examination a number of other perennial grasses, etc. are found typically associated with Themeda, especially in well managed camps.

To gain more information as to which species constitute the typical Themeda-grassveld community, the data from 12 stands at the Glen College of Agriculture were analysed and compared. These analyses are presented in Table 13.

This table gives the composition of Themeda veld on sandy-loam soils. It is a summary of Tables 14, 15 and 16 which are discussed later in this chapter and includes the data of botanical surveys made on the grass plots of a water run-off experiment. This run-off experiment has been in progress at the Glen College of Agriculture for the past 15 years and the run-off has been ascertained on sandy-loam plots of one hundreth of a morgen with a 5 per cent fall. The surveys on these plots were made with the Wheel Point apparatus during April, 1953. Five hundred points were taken on each plot, the lines being 1·5 feet apart and the points 1·2 feet apart within lines.

The species in Table 13 are arranged according to their degree of presence in the 12 stands examined. From Table 13 it is clear that Themeda is constantly present and dominant in this community. Its density and basal cover are principally determined by the system of grazing applied. Where well rested it constitutes up to 92 per cent of the total vegetation (camp rested for seven years), but in overgrazed camps it is almost destroyed, e.g. in camp No. F. 3A it constitutes only 7 per cent of the total vegetation.

Eragrostis lehmanniana and *Tragus koelerioides* are constantly present whatever the treatment. The former occurs in all the stands and the latter in all except plot No. 4 (run-off experiment) where it was trampled out. Generally these species are commonest on the moderately and heavily grazed camps, e.g. on camp No. F. 3A.

Aristida congesta–A. curvata,* *Cymbopogon plurinodis* and *Heteropogon contortus* are usually present with Themeda. They occur in 66 per cent of the stands examined (see Table 13). Except for plot No. 4 (run-off experiment) where they were trampled out, *Aristida congesta–A. curvata*

* These two species are taken together as, at the time the surveys were made, it was not possible to distinguish them with any certainty.

TABLE 13.—*Botanical Survey of* 12 *Themeda Paddocks showing the Percentage of Total Vegetation and Degree of Presence (D. of P.) of the constituting Species. Glen College of Agriculture.*

Camp No.	D. of P. out of 12.	FX. 1D.	MX. B.	Rested.	F. 3A.	FX. 2B.	FX. 2C.	FX. 2D.	FX. 2E.	0	2	3	4
Size in Morgen.		15	20	¼	¼	2	2	2	2	1/100	1/100	1/100	1/100
		Well-managed Cattle.	Heavily-grazed Cattle Sheep.	Rested seven Years.	Heavily-grazed Cattle.	One Month Grazed Three Month Rested Sheep.	Two Month Grazed Two Month Rested Sheep.	Three Month Grazed One Month Rested Sheep.	Continuously Grazed Sheep.	Lightly grazed Burnt Spring.	Rested 15 Years.	Moderately-grazed Sheep.	Heavily-grazed Sheep.
Total percentage Basal Cover.....		24·07	11·10	22·2	18·9	16·85	14·95	13·8	13·2	10·2	24·8	9·8	6·2
Species.	Percentage of Total Vegetation.												
Themeda triandra.....	12	47·50	8·56	92·34	7·41	51·04	42·81	47·10	32·57	56·86	23·39	38·77	16·12
Eragrostis lehmanniana..	12	1·34	0·45	0·45	6·87	2·08	1·67	1·45	7·20	11·77	0·81	10·20	61·29
Tragus koelerioides.....	11	9·35	6·08	1·35	76·71	5·34	11·71	14·49	7·95	5·88	0·81	14·28	—
Aristida congesta and *A. curvata*.....	8	0·62	15·54	—	2·64	—	1·0	2· 9	3·03	5·88	—	20·4	—
Cymbopogon plurinodis..	8	10·18	—	0·90	—	2·37	1·67	3·62	4·16	1·96	2·42	—	—
Heteropogon contortus...	8	0·63	—	0·45	—	4·75	2·34	1·45	0·38	1·96	8·87	—	—
Digitaria monodactyla...	7	1·03	0·68	3·15	—	2·67	4·35	9·78	1·52	—	—	—	—
Cynodon dactylon.....	7	6·03	3·83	—	0·53	0·59	0·67	—	0·38	—	—	—	3·23
Setaria flabellata.....	6	2·18	—	—	—	1·19	1·34	—	0·38	—	50·0	6·12	—
Eragrostis obtusa.....	6	5·50	11·49	—	—	2·37	3·01	3·62	6·82	—	—	—	—
Eragrostis superba.....	6	0·84	—	0·90	1·59	0·59	0·33	—	—	—	—	—	6·46

Camps FX. 2, B to E, were grazed by sheep for eight years, i.e. from 1937 to 1944 and were totally rested from 1945 to 1953.

TABLE 13.—*Botanical Survey of 12 Themeda Paddocks showing the Percentage of Total Vegetation and Degree of Presence (D. of P.) of the constituting Species. Glen College of Agriculture* (contd.).

Camp No.	D. of P. out of 12.	FX. 1D.	MX. B.	Rested.	F. 3A.	FX. 2B.	FX. 2C.	FX. 2D.	FX. 2E.	0	2	3	4
Size in Morgen.		15	20	¼	¼	2	2	2	2	1/100	1/100	1/100	1/100
		Well-managed Cattle.	Heavily-grazed Cattle Sheep.	Rested seven Years.	Heavily-grazed Cattle.	One Month Grazed Three Month Rested Sheep.	Two Month Grazed Two Month Rested Sheep.	Three Month Grazed One Month Rested Sheep.	Continuously Grazed Sheep.	Lightly grazed Burnt Spring.	Rested 15 Years.	Moderately-grazed Sheep.	Heavily-grazed Sheep.
Aster muricatus	6	0·84	6·98	—	—	0·30	2·01	1·45	4·55	—	—	—	—
Sporobolus fimbriatus	5	1·86	—	—	—	5·34	4·01	1·81	0·38	—	—	—	—
Nenax microphylla	5	0·10	—	—	1·06	0·59	0·67	1·45	1·89	—	—	—	—
Digitaria eriantha	4	3·02	—	—	—	11·87	14·72	4·35	—	—	—	—	—
Eragrostis chloromelas	4	—	29·28	—	—	8·01	7·02	0·72	—	—	—	—	—
Triraphis andropogonoides	4	—	—	0·45	—	—	—	—	—	—	5·64	4·09	3·23
Aptosimum depressum	4	0·84	0·22	—	—	—	—	0·36	0·76	—	—	—	—
Pentzia globosa	4	0·22	0·90	—	—	—	—	0·37	1·89	—	—	—	—
Enneapogon scoparius	3	0·32	—	—	—	—	—	4·35	24·62	—	—	—	—
Elyonurus argenteus	3	0·53	—	—	—	0·89	—	—	—	1·96	—	—	—
Hermannia depressa	3	1·86	1·35	—	—	—	—	—	0·38	—	—	—	—
Mariscus capensis	3	—	—	—	—	—	—	—	—	1·96	—	6·12	6·45
Grasses rarely present	1–2	2·19	4·73	—	2·12	—	0·67	0·72	0·38	9·80	8·06	—	—
Shrubs and forbs rarely present	1–2	3·02	9·91	—	1·06	—	—	—	0·76	1·96	—	—	3·22
TOTAL PERCENT VEGETATION		100·0	100·0	99·99	99·99	99·99	100·0	99·99	100·0	99·99	100·0	99·98	100·0
NUMBER OF SPECIES		20	12	8	7	16	16	16	17	8	7	7	6

Camps FX. 2, B to E, were grazed by sheep for eight years, i.e. from 1937 to 1944 and were totally rested from 1945 to 1953.

are most abundant on heavily grazed camps (e.g., camp MX. B, etc.). *C. plurinodis* and *H. contortus* are on well managed camps (see also Table 14). *Digitaria monodactyla* and *Cynodon dactylon* occur in 58 per cent of the stands and are often associated with Themeda. The former is usually on well rested camps and the latter pioneer is most abundant on heavily grazed camps. They seem to be antagonistic to each other. On the camps where the one species is common the other is either absent or scarce.

Setaria flabellata, *Eragrostis obtusa* and *E. superba* occur in 50 per cent of the stands. The first is often on well rested camps (e.g., No. 2) and *E. obtusa* principally on heavily grazed camps (e.g., MX. B, FX. 2C, etc.).

Sporobolus fimbriatus, *Digitaria eriantha*, *Eragrostis chloromelas* and *Triraphis andropogonoides* are often with Themeda and occur in 34 to 42 per cent of the total stands.

Elyonurus argenteus and *Enneapogon scoparius* are rare. The former is usually on well managed camps and the latter usually on limestone soils.

Of the shrubs and shrublets *Nenax microphylla* and *Aster muricatus* are in 42 to 50 per cent of the stands. They are conspicuous on moderately grazed and rested camps but disappear as a result of severe trampling.

Aptosimum depressum, *Pentzia globosa*, *Hermannia depressa* and *Mariscus capensis* occur in only 25 to 30 per cent of the stands. They occur on rested as well as on heavily grazed paddocks.

(*c*) Comparison of Well Managed and Overgrazed Themeda-veld.

To gain more information on the composition of Themeda-veld occurring on the bults, flats and plains, as well as on the botanical changes caused by overgrazing, botanical analyses were made with the Wheel Point apparatus. Two adjoining bultveld camps FX. 1D and MX. B, at the Glen College of Agriculture (see also map No. 1) were surveyed and compared. The soil in these two camps is a uniform red to brownish sandy-loam. Camp FX. 1D is 15 morgen in extent and camp MX. B 20 morgen. The former was well managed and was grazed by cattle with a stocking rate, during the past seven years, of five morgen per animal. The rotational grazing system which was applied to camp FX. 1D (and an adjoining mixed Kalkveld-camp FX. 1A) is as follows: As a rule the camps were grazed jointly during the winter and early spring until the first effective summer rains fell. The animals were then concentrated in camp FX. 1A while camp FX. 1D was rested, and kept there as long as the grazing was sufficient (usually until about the end of April) after which both camps were made available. During winter and the dry spring the animals were kept on both camps and the following summer, after the first effective rains, concentrated in camp FX. 1D whilst camp FX. 1A was rested. As far as the veld permitted, this rotation was repeated from year to year. Camp MX. B has been heavily and more or less continuously grazed for at least the past 30 years by both cattle and sheep. The analyses were made in the middle of April, 1952, and the plants are arranged in Table 14 according to their life-span, grazing value and basal cover. The table shows the basal cover, statistical differences of the data, and the percentage of the total vegetation constituted by each species.

TABLE 14.—*Botanical Survey of a Well-managed* 15-*morgen Themeda-camp* (FX. 1D) *and an adjoining* 20-*morgen Camp* (MX. B), *heavily Grazed by Cattle and Sheep*: 4,000 *points taken in each Camp*; *Wheel Point Method. Lines* 11 *to* 12 *Yards apart*; *Points* 3·14 *Yards within Lines.*

Plant Species.	FX. 1D Percentage Basal Cover.	MX. B Percentage Basal Cover.	Value of t.	FX. 1D Percentage of Total Veg.	MX. B Percentage of Total Veg.
1. *ARISTIDA CONGESTA* AND ANNUAL GRASSES.					
A. congesta and *A. curvata*	0·15	**1·725**	7·31†	0·62	15·54
Tragus racemosus	—	0·45	4·16†	—	4·05
Brachiaria eruciformis	—	0·05	1·41	—	0·45
TOTAL	0·15	2·225	8·61†	0·62	20·04
2. PERENNIAL GRASSES.					
Themeda triandra	**11·45**	0·95	19·95†	47·5	8·56
Eragrostis chloromelas	—	**3·25**	11·56†	—	29·28
Cymbopogon plurinodis	2·45	—	10·41†	10·18	—
Tragus koelerioides	2·25	0·675	5·88†	9·35	6·08
Cynodon dactylon	1·45	0·425	4·76†	6·03	3 83
Eragrostis obtusa	1·325	1·275	0·5	5·5	11·49
Digitaria eriantha	0·725	—	5·41†	3·02	—
Setaria flabellata	0·525	—	4·77†	2·18	—
Sporobolus fimbriatus	0·45	—	4·16†	1·86	—
Eragrostis lehmanniana	0·325	0·05	2·84†	1·34	0·45
Eragrostis curvula	0·275	—	3·33†	1·15	—
Digitaria monodactyla	0·25	0·075	1·94	1·03	0·68
Eragrostis superba	0·20	—	2·86†	0·83	—
Eustachys paspaloides	0·15	—	2·4*	0·63	—
Heteropogon contortus	0·15	—	2·45*	0·63	—
Elyonurus argenteus	0·125	—	2·24*	0·53	—
Aristida vestita	0·10	0·025	1·34	0·42	0·22
Enneapogon scoparius	0·075	—	1·74	0·32	—
TOTAL	22·275	6·725	20·25†	92·52	60·59
3. SHRUBS, BUSHES AND FORBS.					
(*a*) EDIBLE.					
Aster muricatus	0·20	**0·775**	3·69†	0·83	6·98
Hermannia depressa	**0·45**	0·15	2·45*	1·86	1·35
Indigofera alternans	0·025	0·075	1·0	0·11	0·68
Lotononis leobordea	—	0·05	1·41	—	0·45
Nenax microphylla	0·025	—	1·0	0·11	—
Rhynchosia totta	0·025	—	1·0	0·10	—
TOTAL	0·725	1·05	1·55	3·01	9·46

* Significant difference at P = 0·05 (least significant difference t = 1·96).

† Significant difference at P = 0·01 (least significant difference t = 2·57).

TABLE 14.—*Botanical Survey of a Well-managed* 15-*morgen Themeda-camd* (FX. 1D) *and an adjoining* 20-*morgen Camp* (MX. B), *heavily grazep by Cattle and Sheep:* 4,000 *points taken in each Camp; Wheel Point Method. Lines* 11 *to* 12 *Yards apart; Points* 3ö14 *Yards within Lines.* (continued).

Plant Species.	FX. 1D Percentage Basal Cover.	MX. B Percentage Basal Cover.	Value of t.	FX. 1D Percentage of Total Veg.	MX. B Percentage of Total Veg.
(*b*) OF LITTLE GRAZING VALUE.					
Lycium oxycladum	0·025	**0·25**	2·72†	0·10	2·25
Chrysocoma tenuifolia	0·025	0·225	2·53*	0·10	2·03
Aptosimum depressum	**0·20**	0·025	2·33*	0·83	0·22
Scabiosa columbaria	**0·20**	—	2·86†	0·83	—
Seddera capensis	—	0·125	2·24*	—	1·12
Cyperus usitatus	0·075	0·10	0·38	0·32	0·90
Hibiscus trionum	0·10	0·075	0·38	0·41	0·68
Pentzia globosa	0·05	0·10	0·82	0·21	0·90
Nestlera conferta	—	0·075	1·74	—	0·68
Walafrida saxatilis	0·075	—	1·74	0·32	—
Geigeria africana	0·05	0·05	—	0·21	0·45
Stachys hyssopoides	—	0·05	1·41	—	0·45
Gazania oxyloba	0·025	0·025	—	0·10	0·22
Epaltes alata	0·025	—	1·0	0·10	—
Pterothrix spinescens	0·025	—	1·0	0·11	—
Salvia clandestina var. *angustifolia*	0·025	—	1·0	0·10	—
Solanum panduraeforme	0·025	—	1·0	0·10	—
TOTAL	0·925	1·10	0·78	3·84	9·90
GRAND TOTAL	24·075	11·10	19·6†	99·99	99·99

* Significant difference at P = 0·05 (least significant difference t = 1·96).
† Significant difference at P = 0·01 (least significant difference t = 2·57).

From Table 14 the following conclusions can be drawn:—

(1) The total plant cover of the well managed camp is much higher than that of the adjoining overgrazed camp; the difference is statistically highly significant.

(2) *Themeda triandra* is dominant on the well managed camp and constitutes 47·5 per cent of the total cover. This grass is much less common on the overgrazed camp (8·56 per cent of the total cover). The most common grasses associated with Themeda on camp FX. 1D are *Cymbopogon plurinodis*, *Tragus koelerioides Cynodon dactylon* and *Eragrostis obtusa*, representing respectively 10·18 per cent, 9·35 per cent, 6·03 per cent and 5·5 per cent of the total vegetation.

(3) With overgrazing, veld in which Themeda is dominant is changed into an *Eragrostis chloromelas–Aristida congesta–A. curvata* vegetation. These species represent respectively 29·28 per cent and 15·54 per cent of the total vegetation on camp MX. B.

(4) The cover of *Aristida congesta* and *A. curvata* and other annual grasses is significantly higher in the overgrazed than in the well managed camp. As has been indicated *Aristida congesta–A. curvata* constitute 15·54 per cent of the total vegetation on

camp MX. B and a mere 0·62 per cent on camp FX. 1D. *A. congesta* and annual grasses constitute 20 per cent of the total vegetation on the former and 0·62 per cent on the latter camp. Normally *A. curvata–A. congesta* and other pioneers flourish on overgrazed camps where the climax grasses have been destroyed.

(5) A highly significant difference exists between the total cover of the perennial grasses on the two camps; they constitute 92·5 per cent of the total vegetation on camp FX. 1D and 60·59 per cent on camp MX. B. The following perennial grasses are significantly commoner on the well managed camp (see Table 14): *Themeda triandra*, *Tragus koelerioides*, *Cynodon dactylon* and *Eragrostis lehmanniana*. The following grasses were encountered on the well managed camp only:—

Cymbopogon plurinodis,	*Digitaria eriantha*,
Setaria flabellata,	*Sporobolus fimbriatus*,
Eragrostis curvula,	*E. superba*,
Eustachys paspaloides,	*Heteropogon contortus*,
Elyonurus argenteus and	*Enneapogon scoparius*.

Eragrostis chloromelas is common on the overgrazed camp but absent from the well managed camp. There is little difference between the camps in the cover of the sub-climax grass *Eragrostis obtusa*. The rather unpalatable *Cymbopogon plurinodis* and *Elyonurus argenteus* probably also disappear as a result of severe trampling.

(6) The difference in the total cover of edible bushes, shrubs and forbs and of those inedible or less valuable on the two camps is statistically non-significant. The palatable *Aster muricatus* and *Hermannia depressa* are significantly commoner on the well-managed than on the overgrazed camp. *Lotononis leobordea* is conspicuous on bare patches in camp MX. B and absent from camp FX. 1D.

(7) The following shrubs, forbs, etc., of little grazing value, are statistically commoner on the overgrazed camp: *Lycium oxycladum*, *Chrysocoma tenuifolia* and *Seddera capensis*. *Aptosimum depressum* and *Scabiosa columbaria* occur more on the well managed camp or are restricted to it. The bush cover should normally increase as the grass cover becomes more sparse but in these camps the total difference is statistically non-significant.

From these results it can be concluded that at a stocking rate of five morgen per beast and with a sound system of grazing management, a cover was maintained in which Themeda occupied nearly half of the area covered. In comparison with other surveys made at Glen (see Table 13), the vegetation on this camp is in a good condition and the maximum basal cover encountered in this region was maintained (see photo 15).

(*d*) Botanical Analysis and comparison of a Themeda-camp heavily Grazed by Cattle and a Paddock Rested for the Past Seven Years (Arboretum Plot).

Near the cowbyres at the Glen College of Agriculture is a large Themeda-camp, No. F. 3A, 50 morgen in extent and consisting of a red sandy-loam soil having a slight southern inclination. A survey with the

Wheel Point apparatus was made on this camp during April, 1953. Approximately seven years before the survey was made ¼ morgen of veld towards the south-eastern side of this camp was fenced off with the intention of establishing an arboretum. Trees were planted at distances of 21 feet in rows 21 feet apart but they either died or did not thrive. The only trees left are a few stunted *Eucalyptus* species and a few *Pinus halepensis* (see photo 16). For the past seven years this quarter morgen paddock has been rested completely. The botanical analysis was made to compare its vegetation with the surrounding veld of camp No. F. 3A which during the past six years has been heavily stocked and has carried one cow per 2·3 morgen, with supplementary feed. The surveys were made on ¼ morgen areas.

TABLE 15.—*Basal Cover of a Continually Rested Plot (Arboretum Plot, A) and adjoining Veld (B) heavily Grazed by Cattle*: 1,000 *Points taken with the Wheel Point Apparatus on ¼ Morgen Areas. Lines* 1·75 *Yards Apart*; *Points* 1·57 *Yards within Lines.*

Plant Species.	A. Arboretum.	B. Heavily Grazed.	Value of t.	A. Percentage of Total Veg.	B. Percentage of Total Veg.
1. *ARISTIDA CONGESTA* AND ANNUALS.					
Aristida congesta	—	0·5	2·24*	—	2·64
Schismus barbatus	—	0·4	2·0*	—	2·12
TOTAL	—	0·9	3·01†	—	4·76
2. PERENNIAL GRASSES.					
Themeda triandra	20·5	1·4	14·3†	92·34	7·41
Tragus koelerioides	0·3	14·5	12·6†	1·35	76·71
Eragrostis lehmanniana	0·1	1·3	3·23†	0·45	6·87
Digitaria monodactyla	0·7	—	2·66†	3·15	—
Eragrostis superba	0·2	0·3	0·45	0·90	1·59
Cymbopogon plurinodis	0·2	—	1·42	0·90	—
Heteropogon contortus	0·1	—	1·0	0·45	—
Triraphis andropogonoides	0·1	—	1·0	0·45	—
Cynodon dactylon	—	0·1	1·0	—	0·53
TOTAL	22·2	17·6	2·58†	99·99	93·12
3. SHRUBS AND PERENNIAL HERBS.					
(*a*) EDIBLE.					
Nenax microphylla	—	0·2	1·42	—	1·06
(*b*) OF LITTLE GRAZING VALUE.					
Blepharis integrifolia	—	0·1	1·0	—	0·53
Othonna pallens	—	0·1	1·0	—	0·53
TOTAL OF 3 (*b*)	—	0·2	1·42	—	1·06
GRAND TOTAL	22·2	18·9	1·83	99·99	100·0

* Significant difference at P = 0·05 (least significant difference t = 1·96).

† Significant difference at P = 0·01 (least significant difference t = 2·57).

As the animals grazed through the fence of the arboretum camp 2 to 3 feet of the veld on the inside of the fence was kept short, and was left out when the survey was made. Results of this analysis are given in Table 15. From this table the following can be concluded:—

(1) The heavily grazed camp (B) has a lower cover than the rested camp (A). The difference is not statistically significant. At value of 1·83 was obtained whereas values of 1·96 and higher are significant (where $P = 0·05$). The relatively high cover of the heavily grazed camp can be ascribed to the dominance of the matted *Tragus koelerioides*.

(2) With resting, Themeda is encouraged so that 92·3 per cent of the vegetation on the rested plot consists of this grass, the highest percentage of Themeda recorded in our surveys. The rest of the vegetation on this plot consists of perennial grasses of which *Digitaria monodactyla* is the most abundant.

(3) The only pioneer species encountered on the rested plot is *Tragus koelerioides*—a grass typically found in Themeda-veld in this area. This grass constitutes 76·7 per cent of the total vegetation on the heavily grazed area.

(4) No *Aristida congesta* or annual grasses, which constitute 4·7 per cent of the total vegetation on the heavily grazed camp, were recorded from the rested plot.

(5) *Eragrostis lehmanniana* is significantly commoner on the heavily grazed than on the rested plot. No plants of *Digitaria monodactyla* and *Cymbopogon plurinodis* were encountered on the heavily grazed camp.

(6) Shrubs and forbs are unimportant in both camps. With the Wheel Point survey none were recorded on the rested plot, although a few plants of *Nenax microphylla* and *Othonna pallens* were present. Of the total vegetation of the heavily grazed camp 2·1 per cent consists of shrubs and forbs.

(*e*) Sheep Grazing Experiment on Themeda-Grassveld.

(1) *Original Layout of Experiment.*

From 1937 to 1944, Morris (1944), conducted a grazing experiment on the Glen College of Agriculture to determine the effect on grassveld of sheep grazing under a controlled system. The experiment was on eight morgen of typical bult Themeda-grassveld (see also map No. 1). Initially the veld was more or less uniform and the eight morgen were divided into four paddocks (FX. 2B, FX. 2C, FX. 2D and FX. 2E) of two morgen each. The following treatments were applied to the paddocks:—

Paddock 1.—Grazed by 12 sheep for one month and rested for three months, i.e. three months grazed and nine months rested during the year.

Paddock 2.—Grazed by six sheep for two months and rested for two months, i.e. six months grazed and six months rested during the year.

Paddock 3.—Grazed by four sheep for three months and rested for one month, i.e. nine months grazed and three months rested during the year.

Paddock 4.—Continuously grazed by three sheep.

The experiment was started with 1·5 sheep per morgen. The four month-cycles of grazing and resting were begun annually in spring after the first rains. At the beginning and at the conclusion of this experiment, botanical surveys were made by Morris, but no data are available about the method of survey used. In connection with the individual plant species the following conclusions were reached by Morris:—

Themeda triandra : After 7 to 8 years a large decrease of this valuable grass was noticed in all the paddocks except in paddock 1, where there was a slight increase and spreading. There was a progressive decrease from paddock 2 to 3 and from 3 to 4.

Eragrostis lehmanniana : A decrease of this fairly good grazing grass was noticed on all four paddocks, considerably greater in paddocks 2, 3 and 4 than in paddock 1.

Eragrostis " sp." : This is probably *E. chloromelas* (cf. Table 16). This grass remained more or less the same in all four paddocks.

Aristida congesta : This rather worthless pioneer increased considerably in paddock 3 and 4 in comparison with 1 and 2. In the latter paddocks it was mixed with better grasses.

Tragus koelerioides : This is valuable in colonizing bare soil but of little grazing value. It showed a great increase in paddock 3 and 4.

Enneapogon sp. : This pioneer is not of much grazing value. In a part of paddock 4 a considerable amount was found and its increase must, to a certain extent, be regarded as a result of selective overgrazing by sheep.

Other less common grasses of which changes in density were not noticed by Morris, are: *Digitaria* sp., *Eragrostis superba*, *E. obtusa*, *Setaria* sp., *Fingerhuthia* sp., *Aristida vestita*, *Cymbopogon plurinodis* and *Cynodon dactylon*.

A few encroaching plants were found in the experimental paddocks, e.g. *Othonna pallens*, *Lycium* sp., *Helichrysum* sp. and *Chrysocoma tenuifolia*. They were more noticeable in paddocks 3 and 4 and Morris concluded that the damage done by sheep grazing was more severe in these paddocks.

Morris also showed that because of the varying climatic conditions it was impossible to carry out the proposed grazing procedure consistently and that the paddocks could not carry the same number of sheep throughout the 7 to 8 years. The average number of sheep per morgen per year, throughout the 7 to 8 years, was: Paddock 1, 1·21 sheep; paddock 2,

1·16 sheep; paddock 3, 1·16 sheep and paddock 4, 1·14 sheep. The following is a brief summary of Morris's most important conclusions on the grazing systems:—

(1) None of the grazing systems with sheep alone brought about the desired veld improvement as was expected at the beginning of the experiment for a system with long rest periods.

(2) The carrying capacity of the veld, under a reasonable grazing system (1), is approximately 1·2 sheep per morgen per year. Under less favourable grazing systems (2, 3 and 4), the carrying capacity is lower and the damage to the veld greater.

(3) Of the four grazing systems it appears that many sheep for a short period, followed by a rather long period of rest (as in paddock 1), gives the highest carrying capacity and also causes least damage to the veld.

(4) The longer the grazing period and the shorter the intervals of rest (even with few sheep) the worse is the effect on the veld and the lower is the carrying capacity. Continuous grazing caused most damage and gave the lowest carrying capacity.

(5) These results, even the results of the best of the four grazing systems, do not offer a solution to the *Aristida congesta* problem. Where the system of sheep grazing alone was applied the high occurrence of *A. congesta* in comparison with the adjoining camps grazed by cattle was rather marked.

(6) With sheep grazing alone, much selective grazing usually takes place. The result is that unwanted plants afterwards predominate over the better grass types.

(7) The solution to the problem of veld deterioration in the low rainfall grassveld areas may lie in the partial or total replacement of sheep farming by cattle farming with a sound system of grazing management.

(2) *Analyses in* 1953.

From 1945 to the end of 1953 these four paddocks were closed and rested, except that once or twice during the nine years of rest bedding was cut, in winter, from paddocks 1 and 2. They were surveyed in April, 1953, with the Wheel Point apparatus, mainly to see what differences existed on the four paddocks after nine years of continuous resting. It is important to determine how long it would take for heavily grazed paddocks (e.g., 3 and 4) to become revegetated by a cover in which Themeda dominates. Results of this survey are given in Table 16.

TABLE 16.—*Botanical Survey of the Sheep Grazing Paddocks, No.* FX. 2. 2,000 *Points taken on each Paddock with the Wheel Point Apparatus. April,* 1953. *Lines* 6·2 *Yards apart; Points* 1·57 *Yards apart within Lines.*

Paddock No.	(1) FX. 2B.		(2) FX. 2C.		(3) FX. 2D.		(4) FX. 2E.		Value of F.
Treatment.	One Month Grazed Three Months Rested.		Two Months Grazed Two Months Rested.		Three Months Grazed One Month Rested.		Continuously Grazed.		
	Percentage Basal Cover.	Percentage of Total Veg.	Percentage Basal Cover.	Percentage of Total Veg.	Percentage Basal Cover.	Percentage of Total Veg.	Percentage Basal Cover.	Percentage of Total Veg.	
1. *ARISTIDA CONGESTA* and Annual Grasses.									
Aristida congesta	—	—	0·15	1·0	0·40	2·90	0·40	3·03	3·29*
2. PERENNIAL GRASSES.									
Themeda triandra	**8·60**	51·04	**6·40**	42·81	**6·50**	47·10	**4·30**	32·57	10·25*
Enneapogon scoparius	—	—	—	—	0·60	4·35	3·25	24·62	51·4*
Digitaria eriantha	2·0	11·87	2·20	14·72	0·60	4·35	—	—	19·47*
Tragus koelerioides	0·90	5·34	1·75	11·71	2·00	14·49	1·05	7·95	4·05*
Digitaria monodactyla	0·45	2·67	0·65	4·35	1·35	9·78	0·20	1·52	7·43*
Eragrostis chloromelas	1·35	8·01	1·05	7·02	0·10	0·72	—	—	14·8*
Eragrostis lehmanniana	0·35	2·08	0·25	1·67	0·20	1·45	0·95	7·20	5·54*
Eragrostis obtusa	0·40	2·37	0·45	3·01	0·50	3·62	0·90	6·82	1·87
Sporobolus fimbriatus	0·90	5·34	0·60	4·01	0·25	1·81	0·05	0·38	6·33*
Heteropogon contortus	0·80	4·75	0·35	2·34	0·20	1·45	0·05	0·38	6·1*
Cymbopogon plurinodis	0·40	2·37	0·25	1·67	0·50	3·62	0·55	4·16	0·82
Setaria flabellata	0·20	1·19	0·20	1·34	—	—	0·05	0·38	1·89
Elyonurus argenteus	0·15	0·89	—	—	—	—	—	—	3·0*
Cynodon dactylon	0·10	0·59	0·10	0·67	—	—	0·05	0·38	0·73
Eragrostis superba	0·10	0·59	0·05	0·33	—	—	—	—	1·23
Fingerhuthia africana	—	—	—	—	0·10	0·72	0·05	0·38	1·23
Sporobolus ludwigii	—	—	0·10	0·67	—	—	—	—	2·0
TOTAL	16·70	99·10	14·40	96·32	12·90	93·47	11·45	86·74	8·44*

*According to the test of Heterogeneity the cover is considered to be heterogeneous ($F > 2·60$, when $P = 0·05$). In all the other cases the cover was found to be homogeneous.

TABLE 16.—*Botanical Survey of the Sheep Grazing Paddocks, No.* FX. 2. 2,000 *Points taken on each Paddock with the Wheel Point Apparatus. April,* 1953. *Lines* 6·2 *Yards apart; Points* 1·57 *Yards apart within Lines.* (contd.)

Paddock No.	(1) FX. 2B.		(2) FX. 2C.		(3) FX. 2D.		(4) FX. 2E.		Value of F.
Treatment.	One Month Grazed Three Months Rested.		Two Months Grazed Two Months Rested.		Three Months Grazed One Month Rested.		Continuously Grazed.		
	Percentage Basal Cover.	Percentage of Total Veg.	Percentage Basal Cover.	Percentage of Total Veg.	Percentage Basal Cover.	Percentage of Total Veg.	Percentage Basal Cover.	Percentage of Total Veg.	
3. SHRUBS AND HERBS.									
(*a*) EDIBLE.									
Aster muricatus	0·05	0·30	0·30	2·01	0·20	1·45	0·60	4·55	3·76*
Nenax microphylla	0·10	0·59	0·10	0·67	0·20	1·45	0·25	1·89	0·69
TOTAL	0·15	0·89	0·40	2·68	0·40	2·90	0·85	6·44	3·79*
(*b*) OF LITTLE GRAZING VALUE.									
Pentzia globosa	—	—	—	—	0·05	0·36	0·25	1·89	3·78*
Aptosimum depressum	—	—	—	—	0·05	0·36	0·10	0·76	1·23
Blepharis integrifolia	—	—	—	—	—	—	0·05	0·38	1·00
Helichrysum zeyheri	—	—	—	—	—	—	0·05	0·38	1·00
Hermannia depressa	—	—	—	—	—	—	0·05	0·38	1·00
TOTAL	—	—	—	—	0·10	0·72	0·50	3·79	7·57*
GRAND TOTAL	16·85	99·99	14·95	100	13·80	99·99	13·20	100	4·12*

*According to the test of Heterogeneity the cover is considered to be heterogeneous ($F > 2·60$, when $P = 0·05$). In all the other cases the cover was found to be homogeneous.

When the data of each species as well as the values of the total cover are compared on the 4 paddocks the heterogeneity test must be applied first (see Chapter 4). The formula for this test is given by Tidmarsh and Havenga (1955). Where the data are heterogeneous (see Table 16) the significance of the differences between any pair of values is determined directly from Figures Nos. 15, 16 and 17, published by Tidmarsh and Havenga. The paddocks are compared and Table 17 indicates which of the differences are statistically significant.

TABLE 17.—*Summary of Significant Differences in Basal Cover between Individual Plots.*

Basal Cover of.	Paddocks Compared.					
	1–2.	2–3.	3–4.	1–3.	2–4.	1–4.
TOTAL BASAL COVER				0		0
TOTAL COVER OF PERENNIAL GRASSES				0	0	0
Aristida congesta				x		x
Themeda triandra	0		0	0	0	0
Enneapogon scoparius		x	x	x	x	x
Digitaria eriantha		0	0	0	0	0
Tragus koelerioides	x		0	x		
Digitaria monodactyla		x	x	x	0	
Eragrostis chloromelas		0		0	0	0
Eragrostis lehmanniana			x		x	x
Sporobolus fimbriatus				0	0	0
Heteropogon contortus				0	0	0
Total Cover of Edible Shrubs and Herbs						x
Aster muricatus	x		x			x
Total Cover of Inedible Shrubs and Herbs			x		x	x
Pentzia globosa					x	x

0 = former significantly higher than latter.
x = former significantly lower than latter.

Since the range of treatments applied, represents a regular series and the vegetal trends show fairly close conformance to this series it is reasonable to conclude that the differences, where significant, are probably due to the differences in treatment.

An examination of Tables 16 and 17 reveals the following:—

(1) As could be expected the greatest difference in the basal cover exists between paddocks 1 and 4, the differences in the cover of 14 species, or groups of species, being significant. The total basal cover, total cover of perennial grasses and cover of five perennial grass species, viz. *Themeda triandra*, *Digitaria eriantha*, *Eragrostis chloromelas*, *Sporobolus fimbriatus* and *Heteropogon contortus* are significantly higher on the well rested plot (No. 1) than on paddock 4 which was grazed continuously. On the other hand the pioneers *Aristida congesta* and *Enneapogon scoparius*, the sub-climax *Eragrostis lehmanniana* and the shrubs and herbs are significantly more frequent on paddock 4 than on paddock 1.

A marked difference exists between the basal cover of plots Nos. 1 and 3 and between Nos. 2 and 4; in both cases the cover of 11 species (or groups) was found to differ significantly. The difference between paddocks 1 and 3 (where both the total basal cover and cover of perennial grasses differ significantly) is greater than between paddocks 2 and 4 where there is no significant difference in the total basal cover but only in that of the perennial grasses.

When paddocks 3 and 4 are compared the basal cover of eight species and groups is found to differ significantly. There is a significant decrease from plot Nos. 3 to 4 of *Themeda*, *D. eriantha* and *T. koelerioides* and a significant increase in the cover of *E. scoparius*, *Digitaria monodactyla*, *E. lehmanniana*, *Aster muricatus* and the total cover of inedible shrubs and herbs.

From paddocks 2 to 3 there is a significant increase in the basal cover of *E. scoparius* and *D. monodactyla* only, and a decrease in *D. eriantha* and *E. chloromelas*.

There is little difference between the botanical composition of paddocks 1 and 2; Themeda decreases and *T. koelerioides* increases from 1 to 2.

(2) In general there is a gradual decrease in the total basal cover, and total cover of perennial grasses from paddocks 1 to 4. It appears that the total cover and the total cover of perennial grasses decrease when the periods of rest become shorter. Between paddocks 1 and 2 the difference is the smallest, it becomes larger between 2 and 3 and is the largest between 3 and 4, indicating that with increased severity of treatment there is a progressive deterioration of the veld. Even after nine years of rest the difference in the total cover of these four paddocks is still obvious.

(3) The basal cover of the pioneer *Aristida congesta* on paddocks 3 and 4 is significantly higher than that on paddock 1. In agreement with the findings of Morris (1944), there is (even after nine years of rest) still more of this pioneer on plot No. 3, which had a short period of rest, and on plot No. 4, which was grazed continuously, than on the well rested paddocks.

(4) Except between paddocks 2 and 3 there is a progressive significant decrease of Themeda from paddocks 1 to 4. In general it appears that this valuable grass is least damaged by a grazing system which provides for long rest periods and, on the other hand, is most damaged by continuous grazing. Although these paddocks were totally rested for nine years (after the conclusion of the sheep grazing) the differences in the cover of Themeda are still obvious.

Enneapogon scoparius was not struck in plots Nos. 1 and 2, but shows a significant increase from plot Nos. 3 to 4. The frequency of this grass on paddock 4 can be ascribed to the following: A strip of soil in the centre of this camp is more calcareous than that found on the rest of the camp or on the other paddocks. This was not observed at the beginning of the experiment when the paddock apparently had a more or less homogeneous cover. As a result of continuous grazing Themeda was on this limestone soil replaced by the pioneer *Enneapogon scoparius*, which after nine years' rest is still dominant there.

There is, in general, a distinct decrease from plot Nos. 1 to 4 in the basal cover of the perennial grasses *Eragrostis chloromelas*, *Digitaria eriantha*, *Sporobolus fimbriatus* and *Heteropogon contortus*, although not all the differences between adjacent plots are significant. It seems that all these grasses decrease in cover when grazed with relatively short rest periods.

There is no clear trend in the increase or decrease of the pioneer *Tragus koelerioides* in these plots. With the Wheel Point survey of 1953 it was found that it is significantly more frequent on plots Nos. 2 and 3 than on No. 1, and on No. 3 than on No. 4. Morris (1944) noted that during the grazing treatment this grass increased in paddocks 3 and 4. It was found that on paddock 4 (which consists partly of a calcareous soil) *Enneapogon scoparius* is co-dominant with Themeda. As can be seen from Tables 13 and 18 *E. scoparius* is, in general, much more abundant on limestone soils than *T. koelerioides* and it is therefore quite possible that on the limestone soil of paddock 4 the latter grass is replaced by *Enneapogon scoparius*. On the well rested paddock *T. koelerioides* is replaced principally by *Themeda triandra*.

The sub-climax grass *Eragrostis lehmanniana* (as well as *E. obtusa*) is commoner on paddock 4 than on the rest of the paddocks; it is therefore still more abundant on the continuously grazed plot where the more permanent and leafy grasses decreased.

(5) In general there appears to be a gradual increase in the cover of edible shrubs and herbs from plot Nos. 1 to 4; but only the difference between paddocks 1 and 4 is statistically significant. The cover of the palatable *Aster muricatus* is also higher on paddock 4 than on 1 and 3. Shrubs and herbs of little grazing value were not recorded on the well rested plots Nos. 1 and 2; the cover on the continuously grazed paddock is significantly higher than that on the rest of the plots. The inedible *Pentzia globosa* was not struck on paddocks 1 and 2, and only once on paddock 3; the cover on paddock 4 is significantly higher than that of 1 and 2. In general it appears that with short intermittent periods of rest or none, the grass cover is decreased by sheep grazing and the bush cover increases.

After the nine years of rest camp No. 4, and to a certain extent camp No. 3, still have the most pioneers. Although *Themeda triandra* and other climax grasses occur they are not as frequent as in paddocks 1 and 2.

Although Morris's Sheep Grazing Experiment gave some valuable results it is felt that the conclusions reached must be regarded as tentative. In the first place the plots were laid out on a slope so that the well rested camp (No. 1) was the lowest with a gradual slight increase in level to camp No. 4. It is possible that as a result of this slope the plots were somewhat heterogeneous. The frequency of *Digitaria eriantha* towards the lower parts of paddocks 1 and 2 may be ascribed to this. On the other hand the strip of limestone soil is confined to the highest situated plot (No. 4) only. Furthermore the experimental camps were neither randomized nor replicated. Sound conclusions can only be reached if the plots are randomized and, where possible, replicated. The writer also feels that, for grazing experiments, the camps and the herds were too small.

(*f*) Notes on Some of the Plant Species in Themeda-Grassveld.

(*a*) *Grasses.*

Cymbopogon plurinodis, an erect well-rooted sour grass, is frequently associated with Themeda and often common. Because of its bad taste it is seldom eaten but it disappears as a result of severe trampling [see section (*c*)]. In a vegetative state it can be distinguished from *Heteropogon contortus* and *Themeda triandra* by its unpleasant taste („terpentyn gras") and its longer, narrower leaves. *C. plurinodis* usually grows a few inches higher than the other two grasses. The robust *C. marginatus*, which attains a height of 4 to 5 feet, is rather rare and favours stony places.

Heteropogon contortus has sharply pointed seeds which pierce the hides of sheep and goats. It is well grazed in summer. *Elyonurus argenteus*, locally well known as " suurpol," is conspicuous because its silvery-white spikes appear in spring, usually a few weeks before the other grasses flower. It seldom occurs in large numbers and, as it is a " sour " grass, is only grazed when sprouting in spring. The robust *Anthephora pubescens* attains a height of 2 to 3 feet and has conspicuous whitish spikes, usually in late summer. It affords good summer grazing. Of the genus Digitaria, the broadleaved *D. eriantha* and the small tufted *D. monodactyla* are the most common. They occur with Themeda and occasional dense patches may be found. All the *Digitaria* species found in this area are good sweet grasses. The erect *Setaria flabellata* and *Sporobolus fimbriatus* are usually associated with Themeda and well grazed by stock. With the exception of *Eragrostis curvula*, which may also occur in dense stands of Themeda, various other *Eragrostis* species are regarded as typical sub-climax grasses and are discussed in Chapter 9.

(*b*) *Other Monocotyledonae.*

Except for the grasses, Monocotyledonae are much sparser in this community than the Dicotyledonae. Of the family *Cyperaceae* many species occur, but they never dominate and are generally inconspicuous. *Cyperus usitatus*, *Mariscus capensis* and *Kyllinga alba* are quite abundant in this area. They usually occupy the bare spots between the grass tufts and are often grazed by stock.

Three species of *Commelina* are scattered on open to shady spots in Themeda-grassveld.

Except where they may occur abundantly as indicators of overgrazing, the *Liliaceae* are never dominant. *Bulbine asphodeloides* is often found on overgrazed sandy bults. It has attractive yellow flowers, usually blooms after spring rains, and is unpalatable to stock. Scattered white-flowered individuals of *Anthericum pulchellum* and *A. trichophyllum* are typically associated with Themeda in well managed camps. *Albuca pachychlamys* usually forms small dense clans on overgrazed bults and is a reliable indicator of overgrazing. The showy white-flowered *Urginea langii* attains a height of one foot and the broad leaved *Schizocarpus nervosus* is plentiful on overgrazed camps on Glen. The leaves of the former species do not seem to be poisonous and are grazed by horses. *Ornithogalum pretoriense* occurs gregariously on open places on light sandy soils.

Except for a few species of *Hypoxis*, of which *H. rooperi* is the most common, and for *Boöphone disticha*, the family *Amaryllidaceae* is uncommon in Themeda-grassveld. The seed dispersal of the latter species has been dealt with by Louw (1951).

Poisonous tulps like *Homeria pura* are frequent in Themeda-veld but are most conspicuous on overgrazed camps and in cultivated lands, especially during seasons of good winter and autumn rains (see photo 17). The showy white-flowered *Babiana hypogaea* grows on disturbed or cultivated places on light sandy soils. Its corms are found 6 to 12 inches below the surface and are excavated and eaten by pigs, springhares, etc. *B. bainesii* is very rare.

(*c*) *Dicotyledonae.*

Many ruderals and perennial pioneers occur in overgrazed Themeda-veld (see Chapter 9).

The small perennial herb *Herniaria hirsuta* and the bright yellow-flowered *Vahlia capensis* favour wet depressions in the grassveld.

The important family *Leguminosae* is well represented in this grassveld but its species are usually scattered and intermixed with grasses so that they are not very conspicuous. The thick-rooted shrublet *Elephantorrhiza elephantina* occurs more or less gregariously on the hill slopes and between Themeda on the bults. *Cassia obovata* forms large patches and occurs in well managed bult-veld. Its numerous bright yellow flowers are borne on trailing stems approximately five feet long and relieve the monotony of the grassveld when in bloom during the summer. *Listia heterophylla* and *Lotononis leobordea* are well rooted prostrate pioneers occurring on disturbed places in the grassveld. The former is also common on cultivated lands. *Indigofera alternans*, a small erect perennial herb, *I. cryptantha*, an unpalatable shrub, and the prostrate perennial herb *I. holubii* are encountered on disturbed spots throughout the grassveld. The first is very abundant and has red flowers. *Tephrosia capensis*, *Rhynchosia confusa*, *R. memnonia* and *R. totta* are thick-rooted prostrate legumes frequently associated with Themeda on the bults and flats. They are usually gregarious and are grazed by stock.

Monsonia biflora is a common pioneer on overgrazed veld and in lands. According to farmers it causes " stywesiekte " in cattle if eaten in large quantities. *Euphorbia striata*, an erect perennial herb, is sparsely scattered in the grassveld. *Corchorus asplenifolius* is a yellow-flowered prostrate species common on bare spots.

Several species of *Hibiscus* occur on open spots in Themeda-veld. *H. pusillus* has large yellow flowers with a purple centre and the yellow-flowered *H. malacospermus* and *H. marlothianus* occur occasionally. The genus *Hermannia* is well represented in the grassveld. *Hermannia coccocarpa*, the prostrate *H. depressa* and *H. linnaeoides* are the most abundant. All grow between the grass tufts and are grazed during periods of scarcity.

Oenothera tetraptera, a herb with large white nocturnal flowers, occurs in open places in the grassveld and on roadsides. *Menodora africana* is a small shrublet 2 to 6 inches high with showy yellow flowers and grows between grasses. The occurrence of the small yellow-flowered *Sebaea compacta* is very interesting. It appears in great numbers in heavily grazed Themeda-veld during seasons of heavy winter rains. As stated earlier it was very conspicuous during the relatively wet winter of 1950 and totally absent in the succeeding years when little winter rain fell.

The family *Convolvulaceae* is well represented in this grassveld Prostrate deep rooted herbs with trailing stems, e.g. *Convolvulus ulosepalus*, *C. boedeckerianus*, *C. dregeanus* and *C. sagittatus* are the most common, also *Ipomoea crassipes*, a prostrate large purple-flowered herb and *I. simplex*, an erect pink-flowered herb. *Merremia verecunda* is a prostrate herb and comes in strongly on overgrazed sandy bults at Glen. These plants are of some grazing value and are valuable soil shaders.

Tournefortia tuberculosa may be found on bare sandy patches in this grassveld.

Many species of the genus *Solanum* are found on denuded spots in Themeda-veld. They are either poisonous or of no grazing value. On bults and flats the following are the most common: *S. panduraeforme*, the yellow-flowered *S. rostratum* and the small white-flowered *S. supinum*.

Aptosimum depressum forms large patches on open spaces between grasses on loamy and turfy soils. *Harpagophytum procumbens*, a perennial trailing herb, has large pinkish flowers and large fruits furnished along the edges with rows of horny arms bearing recurved spines. This pioneer comes in strongly on overgrazed sandy soils and its fruits are dangerous to the hoofs of animals. *Proboscidea lutea* is very rare.

Nenax microphylla is frequent in Themeda-veld (see also Table 13)* The prostrate *Blepharis integrifolia* and the trailing *Pisosperma capense* as well as the erect *Scabiosa columbaria* are often found between Themeda tufts.

The *Compositae* are poorly represented in Themeda-veld. The conspicuously white-flowered *Arctotis stoechadifolia* often occurs on disturbed places on sandy-loam soils.

As has been mentioned previously the edible shrublet *Aster muricatus* occurs on many soil types including the lighter soils on the bults and flats. It is commonly associated with Themeda (see also Table 13). Pioneer species like *Nidorella resedaefolia* and *Chrysocoma tenuifolia* are very common and often dominate on denuded and disturbed spots. *Helichrysum argyrosphaerum* and *H. ericaefolium* are common prostrate forms occurring between the grasses on the bults and flats. Weeds and ruderals like *Zinnia multiflora*, *Schkuhria bonariensis*, *Bidens pilosa*, etc., are scattered on disturbed places.

3. KALKVELD.

A different plant community is found on limestone outcrops and on places where the top and sub-soil contain a large amount of lime.

(*a*) Soil Conditions.

As has been indicated in Chapter 1, limestone soil is encountered especially in the central and western parts of this area. In certain places, e.g. at Glen, the limestone is exposed so that typical limestone outcrops or bults occur. Numerous small areas of exposed limestone, from which the superficial sand-covering has been removed by various eroding factors, are found. On these spots a typical Kalkveld community is encountered. Where a thin layer (approximately three inches) of sandy loam top soil occurs on the limestone substratum, typical Kalkveld-plants are also found. The limestone outcrops occur as patches scattered here and there and usually vary in size from a few square yards to 20 morgen or more.

The Kalkveld community is marked by its uniformity and poorness in the number of plant species. Where a thin sandy-loam top soil (approximately six inches thick) occurs on a limestone substratum the plant cover is dominated by Themeda. With overgrazing a predominant Themeda-veld, on this type of soil, is changed into typical Kalkveld vegetation with *Enneapogon* spp., etc. dominating [see sections (*b*) and (*e*)].

There is actually little difference between Themeda-veld occurring on limestone soils and that on deep sandy-loam soils. On the former soil a sparser basal cover is, however, usual [see Themeda Grassveld and section (*f*) of this chapter].

A soil sample of a typical Kalkveld-camp, Fx. 1A at Glen, was analysed by Mr. A. van Schalkwyk. An upper soil sample to a depth of one foot and a deeper sample to a depth of two feet were taken. The upper soil consists of a sandy-loam and the deeper soil of limestone nodules mixed with loamy material. Below a depth of two feet, solid limestone is encountered. The soil is covered by Themeda-grassveld. The results shown hereunder are the averages of duplicate determinations. Except for the loss on ignition which was based on oven dry soil (105° C.) all the analysis were done on air dried samples.

Depth.	pH.	Salts pp. m.	Percentage N.	Percentage P_2O_5 Total.	Percentage CaO Total.	Loss on Ignition.	Percentage Moisture, Hygroscopic.
1 to 12 in.	6·8	60	0·07	0·043	0·190	3·301	1·485
12 to 24 in.	7·3	156	0·08	0·042	0·918	3·669	1·665

It can be concluded that the deeper soil is rich in calcium and salt. It is not very rich in P_2O_5 and the pH lies near the neutral point.

(*b*) The Species Composition of Kalkveld.

In order to obtain information as to which species constitute a typical Kalkveld community the data of six stands were analysed. The Wheel Point apparatus was used at the Glen College of Agriculture and the results are discussed separately later in this chapter. The species in Table 18 are arranged according to their degree of presence in the six stands examined. The criterion for presence is not absolute but is based on the survey lists; only the species struck by the marked spoke of the Wheel Point apparatus were considered.

Table 18 shows that *Themeda triandra*, *Tragus koelerioides* and *Nenax microphylla* occur in all the six stands examined and are constantly present in this community. The basal cover of these species is determined by the grazing system, and the grazing animals (cattle or sheep). On well-managed places, as well as on camps grazed by cattle, Themeda dominates. Themeda is, however, almost totally destroyed by sheep grazing and is generally replaced by *Enneapogon scoparius*. Although *Tragus koelerioides* and *Nenax microphylla* are constantly present in this community they do not constitute more than 11 per cent of the total basal cover in the plots examined. The former is more conspicuous on the sheep-grazed camps.

TABLE 18.—*Botanical Survey of Six Kalkveld Plots showing the Degree of Presence of the constituting Species and the Percentage of the Total Vegetation. Glen College of Agriculture.* 4,000 *Points taken on No.* FX. 1A, 1,000 *Points on each of the Other Plots.*

Camp No.	Degree of Presence out of 6.	FX. 1A.	F. 4D.	S. 2.	Railway Strip.	S. 3 (1).	S. 3 (2).*
Size in Morgen.		15	½	½	1/7	½	½
Treatment.		Well managed.	Grazed by Cattle.	Grazed by Sheep.	Rested but Burned.	Grazed by Sheep.	Grazed by Sheep.
Total Percentage Basal Cover.		18·96	15· 6	13· 0	15· 0	11· 6	12· 5
Species.		Percentage of Total Vegetation.					
Themeda triandra	6	36·93	73·07	2·30	10·0	3·45	5·6
Tragus koelerioides	6	8·84	5·76	10·76	0·67	6·90	4·8
Nenax microphylla	6	3·59	0·64	0·76	0·66	0·86	2·4
Enneapogon scoparius	5	6·33	—	32·30	43·33	56·90	33·4
Aristida vestita	5	9·23	—	0·76	13·33	9·48	17·6
Cynodon dactylon	5	3·30	5·12	14·62	—	6·90	1·6
Aristida congesta	4	3·03	3·84	29·23	—	—	1·6
Cymbopogon plurinodis	4	3·30	0·65	—	18·67	0·86	—
Eragrostis lehmanniana	4	4·09	3·20	7·69	—	—	8·0
Pentzia globosa	4	0·40	—	—	3·33	6·90	6·4
Fingerhuthia africana	4	1·58	—	—	1·33	4·31	4·0
Sporobolus fimbriatus	4	0·92	—	0·76	3·33	—	3·2
Enneapogon brachystachyus	3	0·40	—	—	—	2·58	2·4

*Camp received same treatment as S. 3 (1), 1,000 points taken, lines 10 ft. apart and points 4·71 ft. apart within lines.

TABLE 18.—*Botanical Survey of Six Kalkveld Plots showing the Digree of Presence of the constituting Species and the Percentage of the Total Vegetation. Glen College of Agriculture.* 4,000 *Points taken on No.* FX. 1A, 1,000 *Points on each of the Other Plots* (continued).

Camp No.	Degree of Presence out of 6.	FX. 1A.	F. 4D.	S. 2.	Railway Strip.	S. 3 (1).	S. 3 (2).*
Size in Morgen.		15	½	½	1/7	½	½
Treatment.		Well managed.	Grazed by Cattle.	Grazed by Sheep.	Rested but Burned.	Grazed by Sheep.	Grazed by Sheep.
Total Percentage Basal Cover.		18·96	15· 6	13· 0	15· 0	11· 6	12· 5
Species.		Percentage of Total Vegetation.					
Eragrostis obtusa	3	3·03	1·28	—	—	0·86	—
Osteospermum leptolobum	2	—	—	—	3·33	—	4·0
Eragrostis superba	2	1·05	5·12	—	—	—	—
Heteropogon contortus	2	4·09	—	—	1·34	—	—
Aptosimum depressum	2	1·45	1·28	—	—	—	—
Digitaria monodactyla	2	0·66	—	—	—	—	1·6
Pterothrix spinescens	2	0·53	—	0·76	—	—	—
Grasses seldom present	1	4·20	—	—	—	—	—
Shrubs and forbs seldom present	1	3·0	—	—	0·66	—	3·2
TOTAL PERCENTAGE VEGETATION		99·95	100	99·9	99·9	100	100
Number of species		19	10	10	11	11	14

*Camp received same treatment as S. 3 (1), 1,000 points taken, lines 10 ft. apart and points 4·71 ft. apart within lines.

Enneapogon scoparius, *Aristida vestita* and *Cynodon dactylon* occur in five of the six stands examined and are thus more or less constantly present but neither *E. scoparius* nor *A. vestita* was recorded in the survey of the cattle-grazed camp No. F. 4D. Except in this last camp *A. vestita* occurs in all the stands, independent of the treatment. *E. scoparius* dominates on the sheep-grazed camps and constitutes only a little of the total basal cover on the well-managed cattle-grazed camp. *C. dactylon* is usually also more conspicuous on the sheep-grazed than on the rested or cattle-grazed camps.

Aristida congesta, *Cymbopogon plurinodis*, *Pentzia globosa*, *Fingerhuthia africana* and *Sporobolus fimbriatus* are mostly present and occur in four of the six stands examined. *A. congesta* was not recorded on one camp which was grazed by sheep [S. 3 (1)] but is co-dominant with *E. scoparius* on the other sheep-grazed camp (S. 2). Generally this pioneer is most common on overgrazed places. *C. plurinodis* constitutes 18·6 per cent of the total basal cover on the rested and burnt area. It was not recorded on plots S. 2 and S. 3 (2) which were grazed by sheep. *Eragrostis lehmanniana* is abundant on two of the camps grazed by sheep but is absent from the third. Where it is common, *Cymbopogon plurinodis* is either absent or poorly represented, and conversely. In only one plot, No. Fx. 1A, both species occur with more or less the same frequency. *Pentzia globosa* and *Fingerhuthia africana* constitute more than 6 per cent and 4 per cent respectively of the total vegetation on plots Nos. S. 3 (1) and S. 3 (2). They are much less frequent on the other plots. *Sporobolus fimbriatus* constitutes 3·3 per cent and 3·2 per cent of the total basal cover on the ungrazed veld (railway strip) and plot No. S 3 (2), respectively. It is less frequent in the other plots studied.

Enneapogon brachystachyus and *Eragrostis obtusa* occur in 50 per cent of the stands examined. The former constitutes more than 2 per cent of the total basal cover on plots Nos. S. 3 (1) and S. 3 (2) while the latter constitutes more than 3 per cent of the basal cover on the well-managed camp No. Fx. 1A.

Osteospermum leptolobum, *Eragrostis superba*, *Heteropogon contortus*, *Aptosinum depressum*, *Digitaria monodactyla* and *Pterothrix spinescens* occur in two of the stands examined. *O. leptolobum* and *P. spinescens* are generally found on limestone soils. The others are more characteristically associated with Themeda in the Themeda grassveld community on the bults, flats and plains.

(*c*) Characterisation of Kalkveld and Themeda Grassveld.

Based on the data of the preceding section a characterisation of the Kalkveld and Themeda-veld is attempted. This characterisation can only be preliminary for the samples analysed were too few for a complete floristic characterisation. For characterising plant communities Braun-Blanquet (1932) uses the concept "fidelity" and distinguishes five degrees of fidelity in the attachment of species to a certain community.

The characteristic species (fidelity 5 to 3) are of prime importance for a floristic characterisation of a certain community, and also the best indicators of the ecological condition of the community (see Braun-Blanquet 1932: 64). In Table 19 a summary of Tables 13 and 18 is given.

TABLE 19.—*Fidelity of the Species of the Kalkveld and Themeda Grassveld Communities.*

Fidelity.	Veld Type.	Species.	Occurrence in:	
			Kalkveld.	Themeda-veld.
Fid. 5 Exclusive Species	Kalk-veld	*Enneapogon brachystachyus*.....	P 3–4; A 0·4–3·3	Lacking.
		Fingerhutlia africana.....		
		Osteospermum leptolobum.....	P 2; A 0·5–4·0	Lacking or very rare.
		Pterothrix spinescens.....		
	Themeda-veld	*Eragrostis chloromelas*.....	Lacking or very rare	P 1–2; A 0·3–29
		Triraphis andropogonoides.....		
		Elyonurus argenteus.....		
		Hermannia depressa.....		
		Mariscus capensis.....		
Fid. 4 Selective Species	Kalk-veld	*Nenax microphylla*.....	P 5–6; A 0·6–57	P 0–2; A 0·3–24 seldom present.
		Enneapogon scoparius.....		
		Aristida vestita.....		
	Themeda-veld	*Setaria flabellata*.....	P 0–2; A 1–5 seldom present	P 2–3; A 0·3–50
		Eragrostis superba.....		
		Aster muricatus.....		
		Digitaria eriantha.....		
Fid. 3 Preferential Species	Themeda-veld	*Eragrostis lehmanniana*.....	P 2–4; A 0·6–29 usually less abundant	P 3–6; A 0·4–61 may be abundant.
		Aristida congesta.....		
		Cymbopogon plurinodis.....		
		Heteropogon contortus.....		
		Cynodon dactylon.....		
		Digitaria monodactyla.....		
Fidelity 2 Indifferent Species		*Themeda triandra*.....	P 6; A 0·6–73	P 6; A 0·8–92
		Tragus koelerioides.....		
		Sporobolus fimbriatus.....	P 2–3; A 0·7–6·9	P 2–3; A 0·3–11
		Aptosimum depressum.....		
		Eragrostis obtusa.....		
		Pentzia globosa.....		

P = Degree of Presence (out of 6).

A = Degree of Abundance as percentage of total vegetation.

(1) *Indifferent Species.*

Six species, i.e. *Themeda triandra*, *Tragus koelerioides*, *Sporobolus fimbriatus*, *Aptosimum depressum*, *Eragrostis obtusa* and *Pentzia globosa* occur in both Kalkveld and Themeda grassveld communities. They are without pronounced affinities for either of the two grassveld communities (fidelity 2). *Themeda triandra* and *Tragus koelerioides* are constantly present in both communites. The former usually dominates on well-managed and rested camps and the latter is most common in overgrazed places. *T. triandra* and *S. fimbriatus* occur in both Vlei- and Randjie-veld. *Tragus koelerioides* and *E. obtusa* are common on bare spots in the latter veld types. The species named above are therefore not characteristic for either of the grassveld types.

(2) *Preferential Species.*

Six species named in Table 19 are regarded as preferential species (fidelity 3) of the Themeda-veld, viz. species present in both communities but less abundantly in Kalkveld than in Themeda-veld. These species can thus, to a certain extent, be regarded as characteristic for Themeda-veld. *Cymbopogon plurinodis*, *Heteropogon contortus* and *Digitaria monodactyla* occur, however, rather frequently on the Randjies also; *Aristida congesta*, *Cynodon dactylon* and *Eragrostis lehmanniana* are pioneer sub-climax grasses on bare spots on Randjie-veld.

(3) *Exclusive and Selective Species.*

(*a*) *Kalkveld.*

Four species, i.e. *Enneapogon brachystachyus*, *Fingerhuthia africana*, *Osteospermum leptolobum* and *Pterothrix spinescens* were found exclusively on the samples of Kalkveld investigated (fidelity 5). Three species, i.e. *Nenax microphylla*, *Enneapogon scoparius* and *Aristida vestita* can be regarded as selective species most frequently found in Kalkveld (fidelity 4). They are, however, also occasionally encountered in the Randjie- and Themeda-veld.

(*b*) *Themeda Grassveld.*

Eragrostis chloromelas, *Triraphis andropogonoides*, *Elyonurus argenteus*, *Hermannia depressa* and *Mariscus capensis* are found exclusively in the Themeda-veld and are almost absent from Kalkveld (fidelity 5). *T. andropogonoides* and *E. argenteus* occur rather commonly on the Randjies in this area but are absent from Vlei-veld.

Four other species, i.e. *Setaria flabellata*, *Eragrostis superba*, *Digitaria eriantha* and *Aster muricatus* are regarded as selective species (fidelity 4) most frequently found in Themeda-veld. They are seldom found in Kalkveld and only occasionally in Randjie-veld. *Digitaria eriantha* and *Aster muricatus* are also typically found in Valley–Vlei grassveld.

This preliminary characterisation of the Kalk and Themeda grassveld communities is supported by observations made by the writer when he visited various farms in the area.

It is realized, however, that for a proper characterisation of the different communities a greater number of exact surveys is essential. These surveys should preferably be made on homogeneous plots of equal sizes which are widely scattered throughout the area. The vegetation on these plots should also be in the same stage of development.

(*d*) Rested and Sheep-grazed Kalkveld.

To determine the characteristic species-composition of veld on typical exposed limestone outcrops and bults, and the effect of sheep grazing and continuous rest on the species composition, botanical analyses with the Wheel Point apparatus were made. The Kalkveld constituting the camped-off portion of veld in a private Railway Siding at Glen Agricultural College was the only piece of Kalkveld available which was rested for a long period. This continuously rested strip of veld, indicated below as the Railway strip (300 yards by 5 to 6 yards wide; approximately one-seventh morgen) occurring on the south-eastern side of the Railway line, was surveyed together with a portion of camp No. S. 3 [indicated as No. S. 3 (1)], which adjoins the Railway strip, on 13th August, 1953. The latter piece of veld, No. S. 3 (1), is half a morgen in extent (approximately 300 yards by 17 yards wide).

The soil is exposed limestone with a 2° to 5° inclination. Camp No. S. 3 has been grazed by sheep for at least the past 13 years. It received annual rest periods varying from 1 to 10 months and carried, during the past six years, one sheep per 1·1 morgen throughout the year. The Railway strip was totally rested for 30 years or longer, but was burnt in early winter and sometimes twice annually. Results of this analysis, as well as the statistical differences, are presented in Table 20. As the same number of points were taken in these areas the results could be analysed statistically.

TABLE 20.—*Botanical Analysis of a Part of Camp No. S. 3 (½ Morgen Area) Grazed by Sheep and an adjoining Camped-off Strip of Veld (one-seventh Morgen) occurring in a Private Railway Siding at the Glen College of Agriculture*: 1,000 *Points*; *Lines* 10 *Feet apart on Camp No. S. 3, 2½ Feet apart on Railway Strip*; *and Points* 4·71 *Feet apart within Lines.*

Plot.	S. 3.	Railway Strip.	Value of t.	S. 3.	Railway Strip.
	Percentage Basal Cover.			Percentage of Total Vegetation.	
1. PERENNIAL GRASSES.					
Enneapogon scoparius	6·6	6·5	0·09	56·9	43·33
Cymbopogon plurinodis	0·1	2·8	5·0†	0·86	18·67
Aristida vestita	1·1	2·0	1·6	9·48	13·33
Themeda triandra	0·4	1·5	2·54*	3·45	10·0
Tragus koelerioides	0·8	0·1	2·34*	6·90	0·67
Cynodon dactylon	0·8	—	2·83†	6·90	—
Fingerluthia africana	0·5	0·2	1·13	4·31	1·33
Sporobolus fimbriatus	—	0·5	2·24*	—	3·33
Enneapogon brachystachyus	0·3	—	1·73	2·58	—
Heteropogon contortus	—	0·2	1·41	—	1·34
Eragrostis obtusa	0·1	—	1·0	0·86	—
TOTAL	10·7	13·8	2·11*	92·24	92·0
2. SHRUBS AND HERBS.					
(*a*) EDIBLE.					
Nenax microphylla	0·1	0·1	—	0·86	0·66
Salsola glabrescens	—	0·1	1·0	—	0·66
TOTAL FOR 2 (*a*)	0·1	0·2	0·58	0·86	1·32
(*b*) OF LITTLE GRAZING VALUE.					
Pentzia globosa	0·8	0·5	0·83	6·9	3·33
Osteospermum leptolobum	—	0·5	2·24*	—	3·33
TOTAL FOR 2 (*b*)	0·8	1·0	0·47	6·90	6·66
GRAND TOTAL	11·6	15·0	2·24*	100	99·98
Number of species	11	12	—	—	—

* Significant difference at P = 0·05 (least significant difference t = 1·96).

† Significant difference at P = 0·01 (least significant difference t = 2·57).

From Table 20 the following can be concluded:—

(1) The rested and burnt veld has a statistically higher total basal cover than the adjoining sheep-grazed area. The perennial grasses also have a statistical higher total basal cover on the rested than on the sheep-grazed area ($P = 0{\cdot}05$).

(2) *Enneapogon scoparius* is, on both camps, the dominating grass. It constitutes 56·9 per cent of the total vegetation on the sheep-grazed and 43·3 per cent on the rested area.

(3) The following perennial grasses occur in a significantly higher percentage on the rested than on the grazed area: *Cymbopogon plurinodis*, *Themeda triandra* and *Sporobolus fimbriatus*. *Aristida vestita* and *Heteropogon contortus* are commoner on the former plot but the differences are not statistically significant. No *Sporobolus fimbriatus* or *Heteropogon contortus* plants were recorded from the sheep-grazed area.

(4) The pioneers *Tragus koelerioides* and *Cynodon dactylon* are statistically commoner on the grazed than on the rested areas. *Eragrostis obtusa* and *Enneapogon brachystachyus* were not found in the rested veld. *Fingerhuthia africana* is commoner on the grazed area; the difference is, however, not statistically significant.

(5) Except for *Osteospermum leptolobum*, which is statistically commoner on the rested area, shrubs and forbs constitute little of the total vegetation. The unpalatable *Pentzia globosa* is most typically associated with the grasses, especially on heavily grazed limestone outcrops.

(6) Although the surveyed plot No. S. 3 is more than twice the size of the Railway strip, only 11 species were recorded from the former while there were 12 from the latter area.

The continuous resting of the Railway strip caused a certain amount of smothering and probably also influenced the botanical composition of the veld. Bare spots occur between the tufts of the rather robust grasses, e.g. *Aristida vestita*, and on these spots *Enneapogon scoparius* is most abundant. The scarcity of *Themeda triandra* may be ascribed to continuous resting and burning. These factors may not be so detrimental to the robust *Cymbopogon plurinodis* and *Aristida vestita* which are more frequent. On the other hand the latter grasses may be regarded as constituents of a post-climax stage of the Kalkveld.

(*e*) Cattle and Sheep Grazing on Kalkveld.

It has been shown by pasture research workers in South Africa (e.g., Morris 1944, Preller 1950, Coetzee 1948), that the influence of cattle and sheep grazing on the natural veld is not the same. Generally sheep graze more closely and more selectively and cause a more rapid and pronounced veld deterioration than do cattle. In the area studied continuous sheep grazing has caused considerable damage to the veld.

To compare the influence of cattle and sheep grazing on the natural veld in this area a botanical survey of parts of two camps was made. The vegetation of the two adjoining camps, Nos. F. 4D and S. 2, at the Glen College of Agriculture, was surveyed with the Wheel Point apparatus on 21st February, 1953. These two camps are on an almost flat bult. Camp No. F. 4D (camp A) is 23 morgen in extent and camp No. S. 2 (camp B) 36 morgen. The soil consists of a limestone substratum which is, in the main, covered by a thin surface layer (approximately 3 to 6 inches)

of a sandy-loam soil. The survey was made on adjoining plots of ½ morgen each where the soil was uniform and representative of a great part of these camps.

Camp A has been grazed by cattle only for at least the past 14 years. During the past seven years it has carried an average of one beast per 3·3 morgen through the year, but during winter and drought supplementary feed was supplied in kraals and on the veld. Camp B has been grazed for the past 14 years by sheep only, with a stocking rate during the past seven years of 1·4 morgen per sheep through the year. Intermittent rest periods varying from 1 to 10 months were given to both camps. These rest periods, however, were not the same in both the camps. Results of this survey are given in Table 21. The plants listed are classified according to their life-span, frequency and grazing value. To compare the cover of the species on the two camps the results were analysed statistically.

TABLE 21.—*Botanical Survey of Two adjoining Kalkveld Camps at Glen. Camp A was Grazed for the past* 14 *Years by Cattle and Camp B by Sheep*: 1,000 *Points, on* ½ *Morgen Plots. Lines* 10 *Feet apart and Points* 4·71 *Feet apart within Lines.*

Plant Species.	Plot A.		Plot B.		Value of t.
	F. 4D Percentage Basal Cover.	Percentage of Total Veg.	S. 2 Percentage Basal Cover.	Percentage of Total Veg.	
1. *ARISTIDA CONGESTA* AND ANNUALS.					
Aristida congesta	0·6	3·84	3·8	29·23	4·91†
2. PERENNIAL GRASSES.					
Themeda triandra	**11·4**	73·07	0·3	2·3	10·8†
Enneapogon scoparius	—	—	4·2	32·31	6·62†
Cynodon dactylon	0·8	5·12	1·9	14·62	2·13*
Tragus koelerioides	0·9	5·76	1·4	10·76	1·05
Eragrostis lehmanniana	0·5	3·20	1·0	7·69	1·29
Eragrostis superba	0·8	5·12	—	—	2·84†
Eragrostis obtusa	0·2	1·28	—	—	1·42
Cymbopogon plurinodis	0·1	0·65	—	—	1·0
Aristida vestita	—	—	0·1	0·76	1·0
Sporobolus fimbriatus	—	—	0·1	0·76	1·0
TOTAL OF 2	14·7	94·20	9·0	69·23	3·96†
3. SHRUBS, BUSHES AND PERENNIAL HERBS.					
(*a*) EDIBLE.					
Nenax microphylla	0·1	0·64	0·1	0·76	—
(*b*) OF LITTLE GRAZING VALUE.					
Aptosimum depressum	0·2	1·28	—	—	1·42
Pterothrix spinescens	—	—	0·1	0·76	1·0
GRAND TOTAL...	15·6	99·96	13·0	99·98	1·66
Number of Species	10		10		

* Significant difference at P = 0·05 (least significant difference t = 1·96).
† Significant difference at P = 0·01 (least significant difference t = 2·57).

From Table 21 the following conclusions can be drawn:—

(1) Although camp A, which was grazed by cattle, has a higher total basal cover than camp B, which was grazed by sheep, the difference is not statistically significant. There is, however, a great difference in the botanical composition of the vegetation.

(2) Plot B has a much higher basal cover of *Aristida congesta* than plot A. The difference is highly significant. With continuous sheep grazing this relatively valueless pioneer is encouraged. On the camp which was grazed by cattle it constitutes only 3·8 per cent of the total vegetation (29·2 per cent in plot B).

(3) Perennial grasses constitute most of the cover of both camps, viz. 94·2 per cent for plot A and 69·2 per cent for plot B; the difference is statistically highly significant. Themeda is dominant on the cattle-grazed plot. The most abundant associated grasses are: *Tragus koelerioides*, *Cynodon dactylon* and *Eragrostis superba*. On camp B Themeda is largely replaced by *Enneapogon scoparius* and *Aristida congesta*, while the most abundant associated grasses, i.e. *Cynodon dactylon*, *Tragus koelerioides* and *Eragrostis lehmanniana* also seem to show an increase. This increase is, except for *Cynodon dactylon*, not statistically significant.

(4) *Eragrostis superba* which constitutes 5·1 per cent of the total vegetation on plot A was not found in plot B. *Enneapogon scoparius* constitutes 32·3 per cent of the total vegetation cover on plot B and was not recorded on plot A. The differences on either side of the boundary of the two camps are most conspicuous.

(5) On both plots shrubs, bushes and perennial herbs are unimportant.

(6) The pioneer *Cynodon dactylon* is encouraged by sheep grazing, and is statistically more frequent on plot B than on plot A ($P = 0{\cdot}05$).

It is evident that (in this case at least) as a result of sheep grazing a veld dominated by Themeda is changed into one dominated by *Enneapogon scoparius* and *Aristida congesta*. Although it would be unwise to generalise on this record, other observations made in the area afford sufficient support for the conclusion that in Kalkveld as well as in Bultveld, Themeda decreases with continuous grazing. In Bultveld Themeda is replaced chiefly by *Aristida congesta–A. curvata* and in Kalkveld by the characteristic *Enneapogon scoparius*.

(*f*) Comparison of the Basal Cover of the Kalkveld Plots.

In the preceding analysis [sections (*d*) and (*e*) of this chapter] statistical comparisons have been made on each occasion between two adjoining camps which can be regarded as parts of one veld type subjected to different treatments.

The question now arises whether the two groups of plots [plots Nos. F. 4D and S. 2, and plots Nos. S. 3 (1), S. 3 (2) and the Railway strip] which lie closely together (and are separated only by a small stretch of Themeda-veld, through which a dry spruit runs) could be regarded as parts of one veld type. To decide this, the five Kalkveld plots Nos. F. 4D, S. 2, S. 3 (1), S. 3 (2) and the Railway strip, on each of which a thousand points were taken with the survey, were compared. A brief comparison is also made between the mixed Kalkveld camp (No. Fx. 1A) and the above-named plots and the results are shown in Table 22.

TABLE 22.—*Botanical Analysis (Percentage Cover) of the Basal Vegetal Cover of the Kalkveld Plots at Glen.* 4,000 *Points on No.* FX. 1A; 1,000 *Points on each of the Other Plots.*

Camp No.	Five Kalkveld Plots.						Camp No. FX. 1A.	
	F. 4D.	S 2.	S. 3 (1).	S. 3 (2).	Rail Strip.	Value of F.	Well managed.	Value of F. (Six Plots.)
Treatment.	C.	S	S.	S.	Rest.			
1. *ARISTIDA CONGESTA* AND ANNUALS.								
A. congesta	0·6	3·8	—	0·2	—	29·75*	0·575	28·7†
Annuals seldom present	—	—	—	—	—	—	0·025	—
2. PERENNIAL GRASSES.								
Themeda triandra	11·4	0·3	0·4	0·7	1·5	88·62*	7·0	60·0†
Tragus koelerioides	0·9	1·4	0·8	0·6	0·1	2·96*	1·675	4·8†
Enneapogon scoparius	—	4·2	6·6	4·3	6·5	17·54*	1·2	35·9†
Aristida vestita	—	0·1	1·1	2·2	2·0	9·96*	1·75	7·74†
Cynodon dactylon	0·8	1·9	0·8	0·2	—	7·49*	0·625	6·54†
Cymbopogon plurinodis	0·1	—	0·1	—	2·8	25·9*	0·625	20·17†
Eragrostis lehmanniana	0·5	1·0	—	1·0	—	5·04*	0·775	3·79†
Fingerhuthia africana	—	—	0·5	0·5	0·2	2·63*	0·30	1·96
Sporobolus fimbriatus	—	0·1	—	0·4	0·5	2·75*	0·175	2·35†
Enneapogon brachystachyus	—	—	0·3	0·3	—	2·25	0·075	2·25†
Eragrostis obtusa	0·2	—	0·1	—	—	1·33	0·575	4·32†
Eragrostis superba	0·8	—	—	—	—	8·05*	0·20	5·82†
Heteropogon contortus	—	—	—	—	0·2	2·0	0·775	6·79†
Digitaria monodactyla	—	—	—	0·1	—	1·0	0·125	0·97
Grasses seldom present	—	—	—	—	—	—	0·775	—
TOTAL FOR 2	14·7	9·0	10·7	10·3	13·8	5·74*	16·65	13·14†

*Heterogeneous ($F > 2·38$ at $P = 0·05$). †Heterogeneous ($F > 2·21$ at $P = 0·05$). C = Grazed by cattle. S = Grazed by sheep.

TABLE 22.—*Botanical Analysis (Percentage Cover) of the Basal Vegetal Cover of the Kalkveld Plots at Glen.* 4,000 *Points on No.* FX. 1A; 1,000 *Points on each of the Other Plots* (contd.).

	Five Kalkveld Plots.						Camp No. FX. 1A.	
Camp No.	F. 4D.	S 2.	S. 3 (1).	S. 3 (2).	Rail Strip.	Value of F.	Well managed.	Value of F. (Six Plots.)
Treatment.	C.	S	S.	S.	Rest.			
3. SHRUBS, BUSHES AND PERENNIAL HERBS.								
(*a*) EDIBLE.								
Nenax microphylla	0·1	0·1	0·1	0·3	0·1	0·57	0·68	3·59†
Salsola glabrescens	—	—	—	—	0·1	1·0	—	—
Species seldom present	—	—	—	—	—	—	0·075	—
TOTAL FOR 3 (*a*)	0·1	0·1	0·1	0·3	0·2	0·5	0·755	3·79†
(*b*) OF LITTLE GRAZING VALUE.								
Pentzia globosa	—	—	0·8	0·8	0·5	3·88*	0·075	6·91†
Osteospermum leptolobum	—	—	—	0·5	0·5	3·76*	—	7·07†
Aptosimum depressum	0·2	—	—	—	—	2·0	0·275	2·15
Pterothrix spinescens	—	0·1	—	—	—	1·0	0·10	0·80
Salvia clandestina var. *angustifolia*	—	—	—	0·4	—	4·01*	—	—
Species seldom present	—	—	—	—	—	—	0·50	—
TOTAL FOR 3 (*b*)	0·2	0·1	0·8	1·7	1·0	5·6*	0·95	4·25†
GRAND TOTAL	15·6	13·0	11·6	12·5	15·0	2·46*	18·995	11·51†
Total Percentage Cover of Grazing Value [2 and 3 (*a*)]	14·8	9·1	10·8	10·6	14·0	5·65*	17·405	14·68†
Total Percentage Cover of Little Grazing Value [1 and 3 (*b*)]	0·8	3·9	0·8	1·9	1·0	10·65*	1·55	9·18†

*Heterogeneous ($F > 2·38$ at $P = 0·05$). †Heterogeneous ($F > 2·21$ at $P = 0·05$). C = Grazed by cattle. S = Grazed by sheep.

In Table 22 the plants occurring in these plots are arranged according to their life-span and grazing value.

A.—Comparison of the five Kalkveld Plots : *Nos.* F. 4D, S. 2, S. 3 (1), S. 3 (2) *and the Railway Strip.*

For a comparison of the basal cover of the individual species and of the total cover of groups of species on the five plots the test of heterogeneity must be applied first.

As can be seen from Table 22 the data of most species and groups of species are heterogeneous and in these cases the t-test was applied. [Consult Figures Nos. 9, 10 and 11, published by Tidmarsh and Havenga (1955) for t values.] The basal covers of the species and groups of species on the individual plots are compared with each other and Table 23 indicates which of these differences are statistically significant.

As can be seen from Tables 22 and 23 there are resemblances as well as differences in the botanical composition of the five Kalkveld plots. Although the treatments were not replicated it seems that the following conclusions can be made from these two tables:—

(1) There is a general resemblance in the species composition of these Kalkveld plots, especially between plots Nos. S. 2, S. 3 (1), S. 3 (2) and the Railway strip. A total of 22 species was recorded in the five plots and of these species 12 occur in three or more of these plots. *Themeda triandra* and *Tragus koelerioides* which can be regarded as indifferent species (cf. Table 19), occur in all the five plots. *Nenax microphylla* which also occurs in all five plots is, however, a more selective species which prefers limestone soils. The pioneer *Cynodon dactylon* was in four out of the five plots surveyed, but as it occurs in most veld types it is also of little differentiating value. On the other hand *Enneapogon scoparius* and *Aristida vestita* occur in four of the five plots and are characteristic species of Kalkveld. Both species are, however, absent from plot No. F. 4D which was grazed by cattle. *Cymbopogon plurinodis*, *Eragrostis lehmanniana*, *Sporobolus fimbriatus*, *Pentzia globosa* and *Fingerhuthia africana* occur in three of the five plots examined. Except for the last, which is a rather exclusive Kalkveld species, the species are found in various veld types and are thus of little differentiating value. Of the remaining 10 species occurring in one or two plots only, *Enneapogon brachystachyus* is the only typical Kalkveld species. *Pterothrix spinescens* and *Osteospermum leptolobum* are also typical Kalkveld species but are seldom abundant. Table 22 shows that plots Nos. S. 2, S. 3 (1), S. 3 (2) and the Railway strip have the more important Kalkveld indicating species in common, and can therefore be regarded as the most typical examples of Kalkveld. This cannot be said of plot No. F. 4D which shows more resemblance to the Themeda-grassveld community occurring on sandy-loam soils. It must be remembered, as has been indicated in section (*e*) of this chapter, that the soil on plot Nos. F. 4D and S. 2 is deeper and that the limestone is covered by a thin surface layer of sandy-loam soil. As these two plots are separated by a fence, it can be assumed that the differences in the species composition and cover are chiefly due to the difference in grazing treatment [see section (*e*)].

TABLE 23.—*Summary of Significant Differences in Basal Cover between Individual Plots.*

Basal Cover of.	Plots Compared.									
	F. 4D–S. 2.	S. 2–S. 3 (1).	S. 3 (1)–S. 3 (2).	S. 3 (2)–R.S.	F. 4D–S. 3 (1).	S. 2–S. 3 (2).	S. 3 (1)–R.S.	F. 4D–S. 3 (2).	S. 2–R.S.	F. 4D–R.S.
TOTAL COVER					O		X	O		
TOTAL COVER OF PERENNIAL GRASSES	O			X	O		X	O	X	
Aristida congesta	X	O			O	O			O	O
Themeda triandra	O				O		X	O	X	O
Tragus koelerioides							O		O	O
Enneapogon scoparius	X	X	O	X	X			X	X	X
Aristida vestita		X	X		X	X		X	X	X
Cynodon dactylon	X	O				O	O		O	O
Cymbopogon plurinodis				X			X		X	X
Eragrostis lehmanniana		O	X	O	O				O	O
Fingerhuthia africana		X			X	X		X		
Sporobolus fimbriatus			X				X	X		X
Eragrostis superba	O				O			O		O
Inedible Shrubs and Herbs, Total		X				X		X	X	X
Pentzia globosa		X			X	X		X		
Osteospermum leptolobum			X			X	X	X	X	X
Salvia clandestina var			X	O		X		X		
TOTAL COVER OF GRAZING VALUE	O			X	O		X	O	X	
TOTAL COVER OF LITTLE GRAZING VALUE	X	O	X			O		X	O	

O = Former significantly higher than latter.
X = Former significantly lower than latter.

(2) There is a marked similarity in the composition of plots Nos. S. 3 (1) and S. 3 (2) which received the same treatment and adjoin each other. There is no significant difference in the total basal cover and total cover of perennial grasses on these plots. The cover of *Enneapogon scoparius* is, however, much higher on plot No. S. 3 (1) than on plot No. S. 3 (2), while the cover of *Aristida vestita* and *Eragrostis lehmanniana* is much higher on plot No. S. 3 (2) than on No. S. 3 (1).

Although there is a great resemblance in the species composition of the Railway strip and plots Nos. S. 3 (1) and S. 3 (2) the basal cover of a number of species and groups of species differs markedly. Comparisons between the cover of the Railway strip and No. S. 3 (1) have been made in section (*d*) of this chapter. The differences between the cover of the Railway strip and plot No. S. 3 (2) and between plot Nos. S. 2 and S. 3 (1) are not very marked. There is also a resemblance in the cover of plots Nos. S. 2 and S. 3 (2). Except for the total basal cover there is little resemblance in the degree of cover of a number of species on the Railway strip as compared with plot No. S. 2. The cover of 13 species, or groups of species, on these plots differs significantly.

There is little resemblance in the basal cover of the cattle-grazed plot No. F. 4D and the adjoining sheep-grazed plot No. S. 2. Comparisons between these plots are made in section (*e*) of this chapter. As can be seen from Tables 22 and 23 the differences in the cover of the cattle-grazed plot No. F. 4D and the sheep-grazed plots Nos. S. 3 (1), S. 3 (2) and S. 2 are marked. Although there is no significant difference in the total cover, total cover of perennial grasses, total cover of species of grazing value and total cover of little grazing value between plot No. F. 4D and the rested Railway strip, the cover of 12 species on these plots differs significantly.

(3) The total basal cover of the cattle-grazed plot No. F. 4D is significantly higher than that of the sheep-grazed plots Nos. S. 3 (1) and S. 3 (2) and the cover on the rested Railway strip is significantly higher than that on No. S. 3 (1). Perennial grasses constitute 94 per cent of the total cover on the cattle-grazed plot and the high cover can be ascribed to the fact that the grasses were not destroyed by cattle grazing. On the other hand, as has been indicated under (1), a thin surface layer of sandy-loam soil occurs in this plot (as well as in No. S. 2) making the surface more favourable for grasses than the limestone soils in plots Nos. S. 3 (1), S. 3 (2) and the Railway strip. The cover of perennial grasses on the cattle-grazed plot No. F. 4D is significantly higher than that on all the sheep-grazed plots; that on the rested Railway strip is second highest and also significantly higher than on the sheep-grazed plots. Themeda constitutes 77 per cent of the total cover of perennial grasses on plot No. F. 4D and this high cover can, as has been indicated above, be ascribed to soil and grazing factors.

(4) (*a*) The cover of *Aristida congesta* is much higher on the sheep-grazed plot No. S. 2 than on the rest of the plots. The grass is, as a rule, much more abundant on sandy-loam than on any other soil type.

(*b*) The pioneer *Tragus koelerioides* is the least abundant on the rested Railway strip and seems to increase on plots which are grazed.

(5) (*a*) The cover of the typical Kalkveld grass *Enneapogon scoparius* is the highest on plot No. S. 3 (1) and on the Railway strip; on plot No. F. 4D it is replaced principally by Themeda.

(*b*) No *Aristida vestita* was recorded from plot No. F. 4D (and only very little on No. S. 2) but it was fairly common in the rest of the plots. In agreement with general observations this grass is most abundant on soils in which exposed limestone occurs [plots Nos. S. 3 (1), S. 3 (2) and the Railway strip consist of exposed limestone.]

(*c*) The basal cover of *Cymbopogon plurinodis* is significantly higher on the Railway strip than on the other plots compared. This grass is probably encouraged by resting and also seems to disappear when grazed and trampled.

(6) The total cover of plants of grazing value [groups 2 and 3 (*a*), Table 22] is significantly higher on the cattle-grazed and the rested plots than on the plots which were grazed by sheep. The palatable plants seem to be least damaged by resting and cattle grazing.

(7) Plants of little grazing value [group 1 and 3 (*b*)] are significantly more frequent on plot No. S. 2 than on all the other plots; the cover on No. S. 3 (2) is also significantly higher than on No. F. 4D and No. S. 3 (1).

There are resemblances as well as differences in the species composition and cover of the species on these five plots but the differences between the cover of the three sheep-grazed plots are less marked than those between the sheep-grazed and cattle-grazed plots or between the sheep-grazed and rested plots. There is a marked similarity between the botanical compositions of plots Nos. S. 3 (1), S. 3 (2), the Railway strip and to a certain extent plot No. S. 2. The cover of plot No. F. 4D differs markedly from that of the rest of the plots but is very like that of Themeda-grassveld. It appears that under cattle grazing the characteristics of Kalkveld are somewhat obscured and only become conspicuous when this veld is grazed by sheep.

B.—Comparison between Camp No. FX. 1A *and the five Kalkveld Plots.*

The botanical composition and basal cover of the well managed mixed Kalkveld camp No. FX. 1A [15 morgen in extent, see section (*g*) of this chapter] is also compared statistically with that of the five Kalkveld plots discussed above. The results are also given in Table 22.

In order to compare the basal cover of the species on the six different plots the test for heterogeneity was applied first. Seeing that different numbers of sampling points were employed on these plots, formula No. 3 (Tidmarsh and Havenga, 1955: 48) was used. Where the cover was heterogeneous the t-test was applied. The basal cover of species on camp No. FX. 1A (on which 4,000 points were taken) is compared with that on the other plots (on which 1,000 points were taken) and formula No. 4 of Tidmarsh and Havenga is used. The value of F. is shown in Table 22 and with few exceptions the basal cover of the species was found to be heterogeneous. Table 24 shows which of the differences in the cover of the species on camp No. FX. 1A, compared with the five Kalkveld plots, are statistically significant.

TABLE 24.—*Summary of Significant Differences in Basal Cover between Individual Plots.*

Basal Cover of:	Plots Compared.				
	FX. 1A–F. 4D.	FX. 1A–S. 2.	FX. 1A–S. 3 (1).	FX. 1A–S. 3 (2).	FX. 1A–R.S.
TOTAL COVER	0	0	0	0	0
TOTAL COVER OF PERENNIAL GRASSES		0	0	0	0
Themeda triandra	x	0	0	0	0
Tragus koelerioides				0	0
Nenax microphylla	0	0	0		0
Enneapogon scoparius	0	x	x	x	x
Aristida vestita	0	0			
Cynodon dactylon		x			0
Aristida congesta		x			
Cymbopogon plurinodis		0		0	x
Eragrostis lehmanniana			0		0
Pentzia globosa			x	x	x
Sporobolus fimbriatus					x
Enneapogon brachystachyus			x	x	
Eragrostis obtusa	0	0	0	0	0
Osteospermum leptolobum				x	x
Eragrostis superba	x				
Heteropogon contortus	0	0	0	0	0
Edible shrubs, etc., total	0	0	0	0	0
Plants of little grazing value, total	0	0		x	
TOTAL PERCENTAGE COVER OF GRAZING VALUE	0	0	0	0	0
TOTAL PERCENTAGE OF LITTLE GRAZING VALUE		x			

0 = former significantly higher than latter.
x = former significantly lower than latter.

From Tables 22 and 24 the following can be deduced:—

(1) In general there is little difference in the botanical composition of the well managed mixed Kalkveld camp and the five Kalkveld plots. All the more typical Kalkveld indicating species, e.g. *Eneapogon scoparius*, *Aristida vestita*, *Enneapogon brachystachyus*, *Fingerhuthia africana* and *Nenax microphylla* occur in camp No. FX. 1A. As might be expected more species were recorded on the 15 morgen camp than on the ½ morgen plots.

(2) On the five Kalkveld plots the cover of *Enneapogon brachystachyus*, *Eragrostis obtusa*, *Heteropogon contortus* and *Nenax microphylla* was found to be homogeneous. If the basal cover of these grasses is, however, compared on the six plots (No. FX. 1A included) the cover of all these grasses is found to be heterogeneous. On the other hand the cover of *Fingerhuthia africana* is heterogeneous when the five Kalkveld plots only are considered and is homogeneous when the six plots are compared.

(3) The total basal cover on the well managed mixed Kalkveld camp (No. Fx. 1A) is significantly higher than that on all the other plots compared. The high total cover, total cover of perennial grasses and cover of Themeda on camp No. Fx. 1A can be ascribed to the following: (*a*) The camp is well managed so that the vegetation is in a good condition and (*b*) the top soil on approximately two-thirds of this camp is sandy-loam (covering a limestone substratum) which carries a much denser grass growth than the limestone occurring especially in plots Nos. S. 3 (1), S. 3 (2) and the Railway strip. Although these treatments were not replicated it appears that the total cover, total cover of perennial grasses and cover of Themeda is the highest on well managed and cattle-grazed areas and decreases under sheep grazing.

(4) *Tragus koelerioides* is most abundant on the well managed mixed Kalkveld camp and on plot No. S. 2. *Enneapogon scoparius* dominates on the sheep-grazed plots and is absent or rare on the two cattle-grazed camps, the cover on the first plots (as well as the Railway strip) being much higher than that on Nos. Fx. 1A and F. 4D. Except in plot No. F. 4D, *Aristida vestita* occurs in all stands irrespective of the treatment. *Cymbopogon plurinodis* was recorded on camp No. Fx. 1A but not on the sheep-grazed plots Nos. S. 2 and S. 3 (2). It is probably encouraged by resting and decreases when grazed. *Eragrostis superba* in the cattle-grazed plot No. F. 4D is significantly more frequent than in the well-managed camp; it was not recorded in the rest of the plots. This palatable grass is more characteristically associated with Themeda in the Themeda-grassveld community; it seems to disappear as a result of sheep grazing. *Heteropogon contortus* was recorded on camp Fx. 1A and on the rested Railway strip only, the cover on the former camp is significantly higher than that on all the other plots. This grass is not common on limestone but occurs most abundantly in the Themeda-grassveld community. In these limestone plots, however, it may have been destroyed by sheep grazing.

(*g*) Botanical Analysis of a Well Managed Mixed Kalkveld-camp.

A botanical analysis of a well managed 15 morgen Kalkveld camp was made in April, 1952. This camp, No. Fx. 1A, is on a bult at the Glen College of Agriculture. The ground has a slight inclination towards the Middelwaterspruit which lies approximately 500 yards from the north-western boundary of this camp. The soil is a shallow sandy loam on a limestone substratum. For a soil analysis, see section (*a*).

On approximately one-third of this camp the sandy loam top soil is absent so that typical limestone outcrops occur. Where the sandy-loam top soil occurs it varies in depth from a few inches to one foot. That the vegetation should be regarded as mixed Kalkveld and Themeda-veld is shown to be true by a detailed analysis as given below.

This camp has been grazed by cattle for the past 10 years or more. During the past six years it has carried one animal on five morgen throughout the year. The grazing system followed is given in section 2 (*c*) of this chapter. The Wheel Point apparatus was used for the survey and the plants in Table 25 are arranged according to their grazing value, frequency and life-span. When the survey was made the veld was luxuriant and seeding.

TABLE 25.—*Botanical Survey of a* 15 *Morgen Well Managed Mixed Kalkveld Camp* (*No.* FX. 1A), *Glen*: 4,000 *Points taken with the Wheel Point Apparatus. Lines* 11 *Yards apart*; *Points* 3·14 *Yards apart within Lines.*

Plant Species.	Percentage Basal Cover.	Percentage of Total Vegetation.
1. *ARISTIDA CONGESTA* AND ANNUAL GRASSES.		
Aristida congesta	0·575	3·03
Setaria verticillata	0·025	0·13
TOTAL FOR 1	0·600	3·16
2. PERENNIAL GRASSES.		
Themeda triandra	7·00	36·93
Aristida vestita	1·750	9·23
Tragus koelerioides	1·675	8·84
Enneapogon scoparius	1·20	6·33
Eragrostis lehmanniana	0·775	4·09
Heteropogon contortus	0·775	4·09
Cymbopogon plurinodis	0·625	3·30
Cynodon dactylon	0·625	3·30
Eragrostis obtusa	0·575	3·03
Eragrostis curvula	0·325	1·71
Fingerhuthia africana	0·30	1·58
Setaria flabellata	0·250	1·32
Eragrostis superba	0·20	1·05
Sporobolus fimbriatus	0·175	0·92
Digitaria eriantha	0·125	0·66
Digitaria monodactyla	0·125	0·66
Enneapogon brachystachyus	0·075	0·40
Elyonurus argenteus	0·050	0·26
Eustachys paspaloides	0·025	0·13
TOTAL FOR 2	16·650	87·83
3. SHRUBS, BUSHES AND PERENNIAL FORBS.		
(*a*) EDIBLE.		
Nenax microphylla	0·680	3·59
Aster muricatus	0·050	0·26
Indigofera alternans	0·025	0·13
TOTAL FOR 3 (*a*)	0·755	3·98
(*b*) OF LITTLE GRAZING VALUE.		
Aptosimum depressum	0·275	1·45
Hermannia depressa	0·20	1·06
Pterothrix spinescens	0·10	0·53
Chrysocoma tenuifolia	0·075	0·40
Pentzia globosa	0·075	0·40
Lycium oxycladum	0·050	0·26
Othonna pallens	0·050	0·26
Scabiosa columbaria	0·050	0·26
Blepharis integrifolia	0·025	0·13
Cyperus usitatus	0·025	0·13
Hibiscus trionum	0·025	0·13
TOTAL FOR 3 (*b*)	0·950	5·01
GRAND TOTAL	18·955	99·98

The following can be said with regard to the data of Table 25:—

(1) The limestone camp has, in comparison with an adjoining overgrazed Themeda camp (No. Mx. B) a dense plant cover (18·95 per cent) which is, however, statistically significantly lower than that of another adjoining well managed Themeda camp (No. Fx. 1D), ($t = 5·6$ at $P = 0·05$; see also Table 14). This dense cover, in comparison with the adjoining overgrazed Themeda camp, can be ascribed to the judicious veld management which was applied.

(2) The basal cover of *Aristida congesta* and annual plants is very low being a mere 0·6 per cent, or 3·1 per cent of the total cover. The low basal cover of these pioneers and annuals shows that the vegetation of this camp was well managed and is in good condition.

(3) Perennial grasses constitute 87·8 per cent of the total vegetation of this camp. *Themeda triandra* is dominant, with 7 per cent basal cover or 36·9 per cent of the total plant cover. As in the other Kalkveld camps *Aristida vestita*, *Tragus koelerioides* and *Enneapogon scaparius* are associated with Themeda. These three make up 9·2 per cent, 8·8 per cent and 6·3 per cent respectively of the total cover. Among the important grasses are *Eragrostis lehmanniana*, *Heteropogon contortus*, *Cymbopogon plurinodis* and *Cynodon dactylon* (see Table 25).

(4) The basal cover of the shrubs, bushes and perennial herbs is 1·7 per cent, approximately 9 per cent of the total vegetation. The edible shrubs make up 4 per cent of the total plant cover and of these *Nenax microphylla* is the most abundant. Of the plants which are of little grazing value *Aptosimum depressum* is the most important and constitutes 1·4 per cent of the total plant cover.

Fingerhuthia africana is a grass which, as far as the writer is aware, occurs *only* on exposed limestone soil, both on rested and on disturbed places. In this camp nearly all is on the highest part (one-third) where the sandy-loam top soil is absent. Themeda is not abundant on the exposed limestone but more in places where a sandy-loam top soil overlies a limestone substratum. Unpalatable grasses like *Cymbopogon plurinodis* and *Elyonurus argenteus* constitute little of the total plant cover (3·5 per cent).

As has been indicated this camp consists of a mixture of Kalk- and Themeda-veld. The composition of the camp as a whole is, however, characteristic of Kalkveld rather than of Themeda-veld and for this reason the camp is considered in section (*b*) of this chapter where it is compared with other Kalkveld plots.

Generally it can be said that the Kalkveld community, under well managed conditions, is characterised by the dominance of Themeda, especially on places where a thin sandy loam top-soil occurs on the limestone. With Themeda, *Tragus koelerioides*, *Cymbopogon plurinodis*, *Eragrostis lehmanniana* and *Heteropogon contortus*, occur most typically. On the limestone outcrops *Aristida vestita*, *Enneapogon* spp. and *Fingerhuthia africana* are typical. On well managed camps the most characteristic associated shrubs and herbs are *Nenax microphylla*, *Aptosimum depressum* and *Hermannia depressa*.

(*h*) Notes on Plants Occurring in Kalkveld.

Generally the dominating plant cover in the Kalkveld community is formed by the grasses. Except for Themeda the grasses of the Kalkveld afford rather poor winter grazing. During the growing period they are palatable, and these Kalkveld camps are best utilized for summer grazing. Although only a few species of the *Gramineae* are confined to limestone soils they form, as has been stated, the dominating flora. Where the top soil contains limestone and the camp is heavily grazed Themeda is usually replaced by *Enneapogon* spp. Themeda is also generally where a sandy loam top-soil occurs on a limestone substratum, and on well managed camps.

The genus Enneapogon is most common and characteristically confined to limestone soils. *E. scoparius* forms small tufts and is most frequent on heavily grazed camps. *E. brachystachyus* is a small tufted pioneer on overgrazed bare places. Being approximately one inch high, it is of some value for sheep grazing but of little value to cattle. The robust *E. cenchroides* reaches a height of 2 to 3 feet and occurs chiefly as a pioneer on bare disturbed sites, e.g. road and Railway sides. This grass is the most conspicuous of the Enneapogons, especially during seasons with a high rainfall. It is, however, of little significance in the area studied. All the above-named species of *Enneapogon* are rarely, if ever, encountered on soil types other than limestone.

Four species of *Aristida* are characteristical of limestone soil. They are fibrous grasses but are well grazed during the spring. The tall erect, wiry *Aristida vestita* and *A. junciformis* are the most common and widely scattered species. The former is often abundant and was not encountered on other than limestone soils. *A. uniplumis* is a valuable summer grass but very rare in this area. It is common in the western and north-western Cape Province. Although these Aristidas may also occur on sandy soils they are usually found on limestone bults. With *Elyonurus argenteus* they are the first to grow after the winter.

Tragus koelerioides, a perennial creeping pioneer and the ruderal *T. racemosus* are abundant on many soil types, including limestone. The former is very common and forms mats; it is of some grazing value to sheep but is too short for cattle. The tufted perennial *Fingerhuthia africana* is conspicuous on well managed limestone camps. Because of its palatability, especially to sheep, it is often overgrazed and replaced by the Aristidas. *Cynodon dactylon* and *Aristida congesta* are common on overgrazed camps on many soil types. The small tufted *Microchloa caffra* may occur on open situations between other grasses.

Five species of *Eragrostis*, i.e. *E. denudata*, *E. curvula* var. *conferta*, *E. truncata*, *E. lehmanniana* and *E. obtusa* are found on this habitat. The two last are the most common and are also well represented in Themeda-veld. *E. curvula*, *E. superba*, *E. chloromelas*, *Setaria flabellata* and *Elyonurus argenteus* are seldom seen on limestone soil and are commoner in Themeda grassveld.

As with the grasses, there are few species of shrubs, bushes and herbs. Only two monocotyledonous species were found which are typically associated with this community, rare in Themeda- and Randjie-veld and absent from other communities. *Androcymbium melanthioides*, with its large conspicuous white bracts, and the small white-flowered *Massonia latifolia* are frequent on limestone soil and shallow sandy loam soil with a limestone substratum. These species are bulbous, winter-spring flowering and are only in evidence during seasons with good winter and spring rains.

The Dicotyledonae are not as abundant as in Themeda-veld or Valley–Vlei grassveld. *Chenopodium album*, *Salsola kali*, *Atriplex suberecta* and *A. semibaccata* are pioneers on overgrazed and denuded spots on various soil types, including limestone. Except for the last species they are of ittle grazing vaiue.

Species of *Hermannia* occur in this habitat and usually favour open spots. *H. linnaeoides* is the most common. *Psoralea obtusifolia* and *Indigofera argyraea* are the only legumes typical of limestone soils. Both form dense mats, rooting at the nodes. The former species may form patches six feet in diameter. They have purple flowers and are grazed to a certain extent. *Lycium hirsutum* and *L. echinatum* form dense encroaching clumps often found on limestone soil.

The evergreen woody shrublet *Nenax microphylla* is typical of limestone soil. It usually attains a height of six inches and is one of the most palatable bushes in the area. Specimens for chemical analysis were collected on a limestone camp No. Fx. 1A at the Glen College of Agriculture. According to the analysis done by Mr. M. C. F. du Plessis of the Glen Agricultural College, the leaves and young twigs contained the following:—

Percentage.	June, 1949.	January, 1950.
" Protein " (crude, percentage N x 6·25).....	7·21	6·03
P_2O_5.....	0·23	0·19
CaO.....	2·06	2·04

The CaO content is high.

The yellow-flowered frost resistant *Othonna pallens* is an important indicator and grows on overgrazed and disturbed places, especially on sandy soils and on limestone outcrops. Although its leaves are nibbled by stock in periods of drought it is of little grazing value and may even be poisonous.

The blue-rayed *Aster muricatus* is typical of open spots on heavy soils and occurs less abundantly on limestone soils. *A. barbatus* and *Hertia ciliata* are restricted to limestone soils where they occur on rested places but are not common. *Helichrysum cerastioides* and *H. dregeanum* are shrublets favouring places where the soil has been disturbed. The spinescent shrub *Pterothrix spinescens* attains a height of one foot and comes in strongly on limestone outcrops. *Nestlera conferta* has numerous yellow flowers and averages a height of nine inches. Although it is frequent on heavy soils it also occurs on limestone. It is browsed by stock but is of little value. The poisonous *Geigeria africana* occurs singly between the grasses in the Kalkveld.

The genus Pentzia is well represented on this habitat. *Pentzia globosa* is the most common and occurs in disturbed sites such as meerkat burrows and overgrazed areas. *Pentzia lanata* favours disturbed places but is uncommon. Both species are inedible. The writer did not find the latter on other than limestone soils. The shrub *Osteospermum leptolobum* attains a height of 1½ feet and is often found and usually restricted to limestone soil. Its grazing value is doubtful.

CHAPTER 9.

DYNAMICS OF THE CHANGES IN THE GRASSVELD.

The succession of the grassveld, together with the ecological and climatic factors which determine it, has been extensively studied in South Africa (e.g., Bews 1918, Potts 1923, Galpin 1927, West 1949, Louw 1951, Goossens undated). In this chapter a contribution is made to our knowledge of grassveld retrogression and succession.

As the successional changes on the natural veld differ from those on fallow lands they are best dealt with separately.

1. IN THEMEDA GRASSVELD.

(*Natural unploughed veld on the Bults and Flats*).

Plant retrogression was especially studied in Themeda grassveld which is the most extensive grassveld type found in the area.

It is generally accepted that the grassveld over great parts of South Africa was probably in a climax stage and has deteriorated considerably since the farming practices of the Europeans were intensified (see *Report of the Desert Encroachment Committee* 1951, de Klerk, 1947, 1951–52; Adamson 1938). In his discussion on the development and succession of the grassland vegetation of South Africa, Adamson states " The community dominated by Themeda is the natural climax over large portions and represents the culmination of a series of phases." He further states that " even with an average rainfall as low as 15 inches, the Themeda climax can be developed in local patches where suitable conditions of shelter and soil are present." According to Potts (1923), Goossens (undated), and others, Themeda is the climax vegetation over large areas of the Orange Free State. Goossens states, however, that 70 to 80 years ago Themeda together with a number of species of the *Andropogoneae*, e.g. *Cymbopogon dieterlenii*, may have formed the climax vegetation over parts of the Orange Free State. He further concludes that Themeda is merely a transitional stage in the grassveld development and that the stock of the pioneer farmers and large herds of game probably checked the succession beyond the Themeda stage. No plants of *C. dieterlenii* were found in the area studied and it seems probable that Themeda and *Cymbopogon plurinodis* may have formed, and still form, the climax community on the bults, flats and plains. *C. dieterlenii* is found only in the eastern Orange Free State.

Before the advent of the European farmer, herds of game animals with different grazing habits roamed the veld. The game moved rapidly from one grazing ground to another so that although the veld was grazed and the trees were browsed, there was a chance for the veld to rest as the animals moved to other spots. With the introduction of domestic grazing animals, the grazing pressure increased. Few camps were made on the farms so that continuous grazing was generally practised. Various research workers in South Africa have stressed the desirability of avoiding continuous grazing and overstocking. Heavy grazing with regular rest periods during the summer is generally advocated. Severe continuous stocking led to selective grazing which left no rest periods for the palatable climax plants.

The results were that the climax community was destroyed and its place was taken by less palatable and hardier plants which were more resistant to cropping and trampling. The Committee which investigated Desert Encroachment (1951), concluded that selective and over-grazing has occurred so universally that there appears to be scarcely a square mile of occupied veld in the Union of South Africa which can confidently be stated as being entirely in the natural condition.

Slight denudation, caused by heavy grazing for not too long periods, results in only a partial destruction of the plants of the climax vegetation which are often the most palatable and sensitive to overtrampling. This denudation does not significantly disturb the soil and, with suitable resting periods, the veld recovers readily. If the denudation results from prolonged heavy over-grazing and trampling the soil is disturbed, the vegetation ousted, and it takes long before the ground is revegetated by the climax species.

It is well known that veld burning also results in a modification of the vegetation but at present this factor plays no role in this area—during the six years of this study the author has not observed any extensive or significant veld fire [see also Potts (1923)].

According to Adamson (1938), the " Dry Grassland " with its less dense cover is easily changed when severely grazed. Small undershrubs like *Selago*, *Pentzia*, *Chrysocoma*, etc., spread as the grasses diminish, so that they become dominant and produce an open karroo-like vegetation. Although Adamson's observations can be endorsed it is not commonly found in this area that perennial grasses are replaced by karroo plants. The writer found that, as a result of overgrazing, the climax grasses on numerous grassy camps are replaced principally by pioneer and ruderal grasses (see also Chapter 8).

(*a*) Climax Stage.

The vegetation on rested and well managed camps on the bults, flats and plains consists of *Themeda triandra* with an admixture of *Cymbopogon plurinodis*, *Setaria flabellata*, *Heteropogon contortus*, *Digitaria* spp. and *Anthephora pubescens*. Under present conditions these species probably form the climax stage of the grassveld occurring on the bults, flats and plains.

A number of surveys were made of the probable climax vegetation and the results are given in Table 26.

TABLE 26.—*Themeda-veld in a Climax Stage. Botanical Composition and* ESTIMATED *Percentage of the Total Basal Cover which Each Species Constitutes.*

Situation of Plot or Camp.	Glen.		Various Grazing Camps.	Brand-fort.	Bloem-fontein.	Western Portion.
	Fx. 3B.	Arbore-tum.*		Keerom, Mooi-doorns.	Tafel-kop.	Lom-bards-drift.
Estimated total basal cover..	Per Cent. 22–25	Per Cent. 22·2	Per Cent. 22–25	Per Cent. 25	Per Cent. 25	Per Cent. 20
Themeda triandra.....	70	92·3	80	85	85	60
Heteropogon contortus.....	6	0·5	4	4	5	2
Cymbopogon plurinodis.....	3	0·9	4	2	2	5
Eragrostis lehmanniana.....	6	0·4	2	2	2	5
Sporobolus fimbriatus.....	2	—	4	2	—	2
Anthephora pubescens.....	2	—	1	—	—	25
Elyonurus argenteus.....	2	—	2	3	—	—
Setaria flabellata.....	5	—	2	—	4	1
Digitaria eriantha.....	2	—	1	2	—	—
Digitaria monodactyla.....	1	3·1	—	—	2	—
Tragus koelerioides.....	1	1·4	—	—	—	—
Triraphis andropogonoides....	—	0·5	—	—	—	—
Eragrostis superba.....	—	0·9	—	—	—	—

* Surveyed with the Wheel Point apparatus. (cf. Table 15).

(1) *Camps at the Glen College of Agriculture.*

(i) *Camp No.* Fx. 3B.

This paddock is two morgen in extent and is part of camp No. Fx. 3. The soil is a sandy loam up to six feet deep which has a slight inclination towards the Middelwaterspruit. On this camp plant lists were compiled in March, 1952, and April, 1953. A few rows of Honey Locust trees were planted, otherwise the veld has been left undisturbed during the past eight years. Previous to this the veld was fairly well managed.

Being neither grazed nor burnt the grasses form a dense cover, estimated at 22 to 25 per cent basal cover, and have probably reached the climax stage with Themeda constituting approximately 70 per cent of the total basal cover. *Heteropogon contortus*, *Setaria flabellata* and *Eragrostis lehmanniana* are the most abundant associates. *E. lehmanniana* occurs especially on places where Themeda is sparse.

Signs of smothering from the accumulation of dry grass are noticed on this paddock. Very few plants of the sub-climax stage (e.g. *Eragrostis obtusa*) or pioneer stage (e.g. *Aristida curvata*) are visible. Only a few scattered trees and bushes occur. These are *Chrysocoma tenuifolia*, *Nenax microphylla*, *Acacia karroo* and *Ziziphus mucronata*, seedlings of the trees were found.

(ii) *Arboretum Camp.*

This camp has been rested for approximately the past seven years and the vegetation is in a climax stage. Themeda occurs as a dominant and constitutes 92 per cent of the total vegetation. *Digitaria monodactyla, Tragus koelerioides, Eragrostis superba* and *Cymbopogon plurinodis* are the most abundant associated species. A detailed discussion is given in Chapter 8 section 2 (*d*).

(iii) *Various Grazing Camps.*

Further species lists were made on parts of the following bult-camps at the Glen College of Agriculture: No. F. 1 (153 morgen), No. D. 7 (25 morgen), No. M. 14 (100 morgen) and No. F. 4c (45 morgen). The soil on these camps is a red sandy loam. They were grazed but well managed. Except near the gates and watering points where the veld is trampled the greatest part of these camps is densely covered by Themeda. In comparison with the camp discussed under (i) there is practically no difference in the botanical composition and ratio of the different species.

(2) *Camps near Brandfort.*

Species lists were made on morgen plots on the farms Keerom and Mooidoorns which lie about two miles south-west of Brandfort in April, 1952, and April, 1953. The areas are part of a level plain, approximately 1,000 morgen in extent and densely covered by Themeda. The veld has been well managed during the past few decades. The total basal cover was estimated to be very slightly higher than that of the camps at Glen and is approximately 25 per cent. All the species named in Table 26, under the above heading, were found on the plots studied on both farms. Trees and shrubs are absent. In isolated spots *Aster muricatus, Cynodon hirsutus* and *Eragrostis lehmanniana* were found.

(3) *Camp near Bloemfontein.*

Part of a camp of one morgen situated on a small bult one mile north-west of Tafelkop (near Bloemfontein) was studied on 29th April, 1953, and a species list was drawn up. This area has a red sand-loamy soil with a 3° to 4° inclination towards south-west. It is densely covered by Themeda and the estimated total basal cover is 25 per cent. *Setaria flabellata* and *Heteropogon contortus* are most abundantly associated with Themeda. *Nenax microphylla* and *Rhus ciliata* are present but sparse.

(4) *Various Camps Scattered throughout the Area.*

Further plant lists were made on part of well managed camps near Mockesdam, Sannaspost, Bloemfontein, Karree and at Lombardsdrift in the western part of the area studied (see map No. 3).

In all the cases investigated Themeda was dominant and except at Lombardsdrift, the associated species were more or less the same as those indicated under (1) and (2).

On the farm Donkerhoek, near Lombardsdrift, the estimated basal cover of the veld was 20 per cent (see Table 26). *Anthephora pubescens* was common and well intermixed with Themeda. It constitutes approximately 25 per cent of the total basal cover. The soil on this farm is light and much more sandy than that in the southern and eastern parts of the area. In general it appears that *Anthephora pubescens* is most frequent on the lighter soils in the western parts of the area.

(5) *Discussion.*

From the results of these surveys it can be concluded that in a climax Themeda-community on the bults and flats, Themeda usually constitutes 70 per cent or more of the total basal cover. *Heteropogon contortus*, *Cymbopogon plurinodis* and *Eragrostis lehmanniana* are constantly associated with Themeda and constitute from 0·4 to 6 per cent of the total cover. Other grasses like *Sporobolus fimbriatus*, *Anthephora pubescens*, *Digitaria* spp., etc., often occur in a Themeda climax community but are generally unimportant.

Although Themeda has an extensive root system and is able to oust its xerophytic neighbours its innovation buds are situated near the soil surface so that it is badly damaged by overgrazing and trampling (Goossens and Stapelberg 1933). With the exception of *Cymbopogon plurinodis* and *Elyonurus argenteus* the associated climax grasses are also palatable. Rowland (1933), in his ecological studies of the Potgietersrus area mentions a strain of Themeda common at Matala's Location on areas which had long been heavily trampled and grazed. It is therefore probable that not all the strains of Themeda are equally sensitive to overgrazing and trampling.

The first signs of the overgrazing of the climax grasses are the increase of bare areas between the tufts and a decrease of the palatable grasses. These bare spots occur most abundantly near the watering points and gates. At this early stage the bare spots are usually surrounded by the climax grasses observed on parts of the following bult-camps at Glen: Nos. F. 3, F. 4, M. 13 and M. 14. If mismanagement is continued the patchiness of the veld becomes progressively worse.

(*b*) Sub-climax Stage.

If Themeda-veld is overgrazed slowly Themeda gradually gives way to sub-climax species but when the denudation is rapid Themeda is usually directly superseded by annuals and pioneers. The species in the sub-climax stage are more xerophytic and are all perennials. Their innovation buds are usually deeper seated so that they are not easily damaged by grazing and trampling. The following are examples: *Eragrostis lehmanniana*, *E. obtusa*, *E. superba*, *E. chloromelas* and *E. barbinoides.*

Overgrazing of Themeda was studied on parts of the following camps at the Glen College of Agriculture: *Camps No.* F. 3 [(*a*) and (*b*); together 98 morgen), No. F. 4 (86 morgen), No. M. 13 (50 morgen) and M. 14 (100 morgen)].

Camp Nos. F. 3 and 4 were heavily stocked with cattle. The first has been stocked at the rate of three morgen per animal for the past six years and camp No. 4 at the rate of six morgen per animal. Additional feed has, however, been given during droughts and in winter. Up to 1951 camps Nos. M. 13 and 14 were privately owned and no grazing records were kept. These camps were, however, heavily stocked; they were grazed by both cattle and sheep and the veld is still badly trampled near the watering points. The parts of these camps at the greatest distance from the watering points are still in a dominant Themeda stage. The soil for the most part is a reddish to brownish sandy loam. The latest observations were made in March, 1952, and March, 1953.

Except on the parts of the camps furthest from watering points and gates, the climax grasses have been replaced to a great extent by sub-climax species and even by pioneers. On many places, e.g. in camp No. F. 3, the bare spots between the Themeda tufts are occupied by *Aristida congesta*, *A. curvata*, *Cynodon* spp., *Tragus koelerioides* and *Eragrostis obtusa* (see also Fig. 7).

The writer has never observed that a retrogressive veld consists entirely of a pure sub-climax (Eragrostis) cover. In general overgrazed veld consists of sub-climax grasses together with many pioneers mixed with isolated tufts of the climax grasses. On naturally revegetated old lands, however, it is possible to find an almost pure stand of *Eragrostis lehmanniana* which represents the sub-climax stage.

Little quantitative data are available but it is estimated that veld in a sub-climax stage would have a total basal cover of approximately 15 per cent. The sub-climax grasses and pioneers may show an increase in the number of individuals but the total basal cover of the veld usually decreases. The tufts of all *Eragrostis* and *Aristida* species occurring in this region are on the average smaller than typical Themeda tufts and usually give a lower basal cover than Themeda. According to observations the total basal cover of veld in the pioneer stage may vary from less than 1 per cent to 12 per cent; in sub-climax veld from 12 per cent to 20 per cent, and on veld in the climax stage from 20 per cent to 25 per cent.

To show the variability in species composition and basal cover of veld in a sub-climax-pioneer-stage three quadrat charts (Fig. 7) were made in camp No. F. 3A.

As has been indicated the soil in this camp is a red sandy loam. The ground has a 3 to 4 degree eastern inclination. Quadrat No. 1 was taken 50 yards from a gate towards the south-eastern side of camp No. F. 3A and quadrats Nos. 2 and 3 near the north-eastern corner of this camp, 10 and 15 yards from the corner, respectively. Quadrat No. 1 is 200 yards from Nos. 2 and 3. On the whole camp No. F. 3A, Themeda is largely replaced by sub-climax and pioneer plants. These quadrats are in veld which is in a sub-climax-pioneer stage. The variation in total basal cover and species composition of these three quadrats is evident.

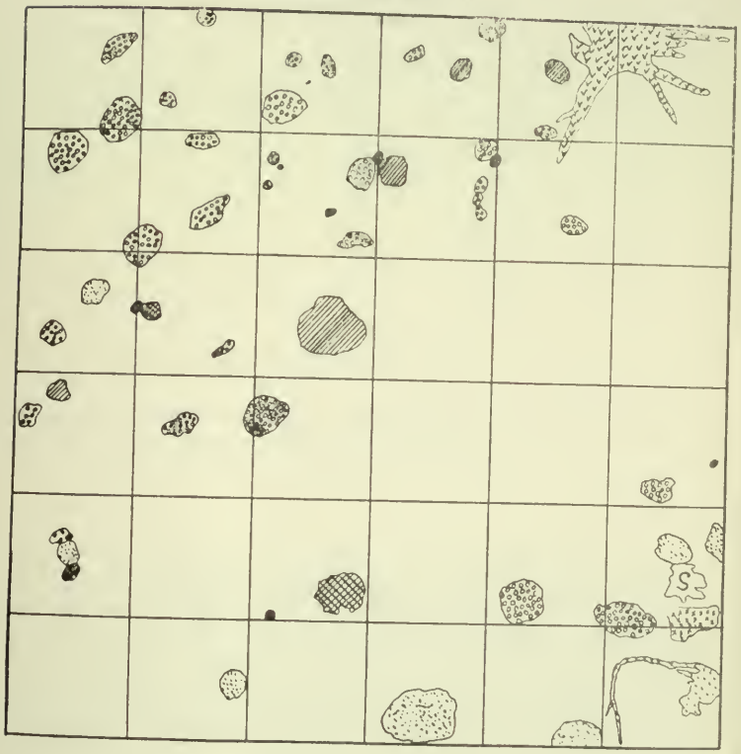
In quadrat No. 1 Themeda is replaced mainly by *Eragrostis obtusa*, *Tragus koelerioides*, *Eragrostis lehmanniana* and *Aristida congesta*, in quadrat No. 2 by *Tragus koelerioides*, *Eragrostis lehmanniana* and *Eragrostis obtusa*, and in quadrat No. 3 by *Cynodon hirsutus* and *Aristida congesta*. The total basal cover in quadrat No. 2 is approximately 16 per cent and is much higher than that in quadrat No. 1 (approximately 8 per cent) and in No. 3 (approximately 6 per cent). Large tufts of Themeda are seen in quadrat No. 2 while those in Nos. 1 and 3 are less abundant and much smaller. In all three quadrats pioneer herbs occur. *Salvia clandestina* var. *angustifolia* is the most common and is constantly present. Bare areas between the Themeda tufts are conspicuous. The pioneer and sub-climax plants colonize these bare patches to a certain extent.

All the sub-climax grasses mentioned produce large amounts of seed, are drought resistant and, although not as leafy and palatable as Themeda, afford valuable grazing. The carrying capacity of veld in a sub-climax stage is two-thirds to half that of a climax Themeda grassveld. With

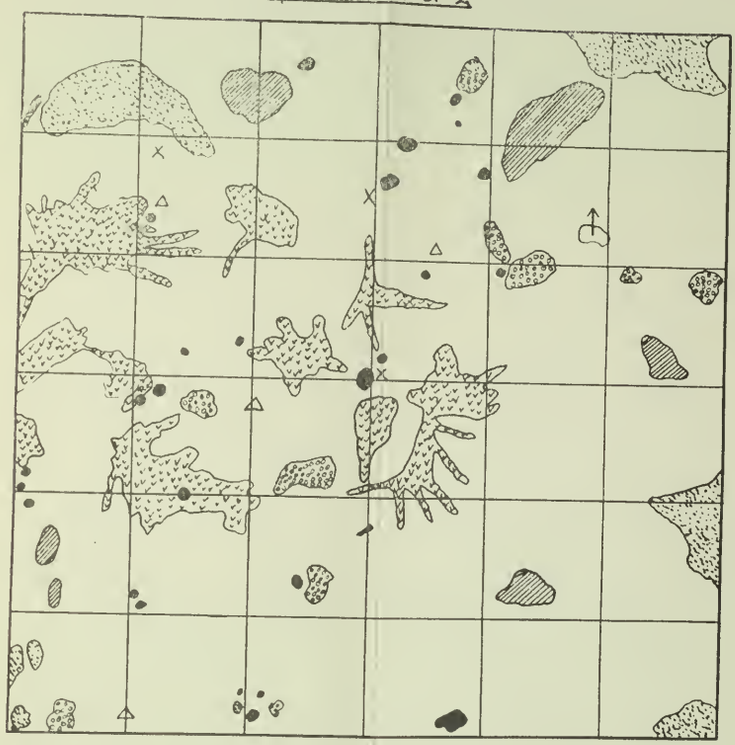
FIGURE 7.

CHART QUADRATS (EACH 1 SQ. YARD) SHOWING THE DISTRIBUTION OF DIFFERENT SPECIES IN A HEAVILY GRAZED BULT-CAMP. CAMP F3(A). GLEN COLLEGE OF AGRICULTURE, 14-12-1953.

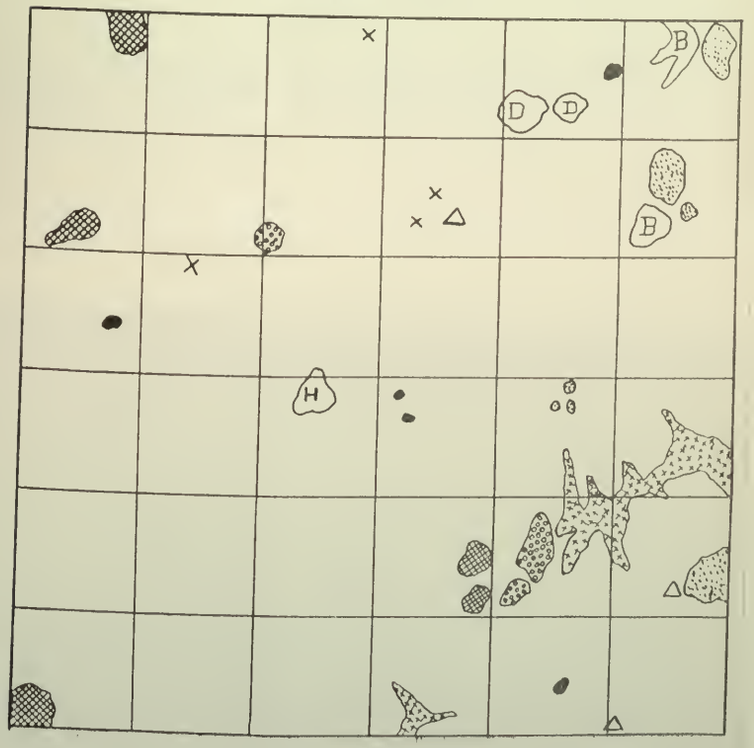
QUADRAT NO. 1



QUADRAT NO. 2



QUADRAT NO. 3



REFERENCE:

- = THEMEDA TRIANDRA.
- = TRAGUS KOELERIOIDES.
- = ERAGROSTIS LEHMANNIANA.
- = ERAGROSTIS OBTUSA.
- = ARISTIDA CONGESTA.
- = CYNODON HIRSUTUS.
- S = ERAGROSTIS SUPERBA.
- D = DIGITARIA MONODACTYLA.
- H = HERMANNIA COMOSA.
- B = BLEPHARIS INTEGRIFOLIA.
- = ASTER MURICATUS.
- • = SALVIA CANDESTINA VAR ANGUSTIFOLIA.
- × = INDIGOFERA ALTERNANS.
- △ = CHRYSOCOMA TENUIFOLIA

heavy grazing the common *Cynodon dactylon*, *C. hirsutus* and *Tragus koelerioides* are very conspicuous. Although characteristic pioneers they are often quite persistent so that they may be superseded directly by the climax species with the exclusion of a typical sub-climax Eragrostis stage.

(*c*) Pioneer Stage.

The pioneer stage was studied on various places scattered throughout this area. The results of these surveys are given in Table 27.

Table 27.—*Themeda-Grassveld in a Pioneer Stage. Botanical Composition and Estimated Percentage of the Total Basal Cover which Each Species constitutes.*

Camp.	Mx. c	Mx. b*	F. 2 and F. 9.
Estimated total basal cover	Per Cent. 12	Per Cent. 11·1	Per Cent. 10
Aristida curvata and *A. congesta*	30	15·5	25
Tragus koelerioides	20	6·1	35
Themeda triandra	10	8·6	5
Cynodon spp	5	4·0	10
Eragrostis lehmanniana	5	0·5	10
Chrysocoma tenuifolia	2	2·0	3
Eragrostis chloromelas	10	29·3	—
Eragrostis obtusa	10	11·5	5
Aster muricatus	5	7·0	2
Nestlera conferta	1	1·0	—
Ruderals, other herbs, shrublets and geophytes	2	14·5	5

* Surveyed with the Wheel Point apparatus (see Table 14).

The following is a short account of the camps, and the results obtained. All the camps occur on the Glen College of Agriculture.

Camp Mx. c.

This camp is 20 morgen in extent and 600 yards from the Middelwaterspruit. The soil is a red sandy loam and has a very small slope to the west. The camp was heavily grazed for 30 years or more. It has an estimated basal cover of 12 per cent. Perennial pioneer grasses occur predominantly and constitute more than 55 per cent (estimated) of the total basal cover. *Aristida curvata–A. congesta* and *Tragus koelerioides* are dominant. Shrublets and herbs are conspicuous between the grass tufts but constitute little of the total cover. Of these *Aster muricatus* and *Chrysocoma tenuifolia* are the most abundant. Most Themeda tufts are on the southern side of this camp, i.e. farthest from the watering point.

Camp Mx. b.

This camp was surveyed with the Wheel Point apparatus. Pioneer and sub-climax grasses are predominant. See Table 14 and Chapter 8, section 2 (*c*) for a discussion.

Camp F. 2 *and* F. 9.

The former camp is 37 morgen and the latter 7·6 morgen in extent. Both were studied and plant lists were made in December, 1952, and April, 1953. The soil is a red sandy loam and has a 2° to 3° slope. For many years these camps were heavily grazed by horses. During the past six years (1947 to 1952) the former camp carried one horse per 5·5 morgen and the latter camp one per 11·3 morgen. Additional feed was, however, supplied during droughts. At the time of the surveys it was obvious that these camps were overgrazed and in a pioneer stage. The estimated basal cover was 10 per cent. The pioneer grasses constitute approximately 70 per cent of the total basal cover. Themeda and associated climax grasses which are abundant in an adjoining well rested camp are very rare in these camps.

Pioneer Species.

From further plant collections and observations the writer found that the following grasses are the commonest pioneers on sandy and sandy-loam soils throughout the area. The commonest species are listed first:

Aristida curvata,	(A)
Tragus koelerioides,	(P)
* *T. racemosus,*	(A)
* *Chloris virgata,*	(A)
Aristida congesta,	(P)
* *Cynodon hirsutus,*	(P)
C. dactylon,	(P)
Tragus berteronianus,	(A)
Eragrostis porosa,	(A)
Trichoneura grandiglumis	(A)

The following pioneers are abundant on heavy turfy and clayey soils:—

* *Tragus racemosus,*	
* *Chloris virgata,*	
* *Cynodon hirsutus,*	
Brachiaria eruciformis,	(A)
Aristida bipartita,	(P)
Sporobolus ludwigii,	(P)
Eragrostis biflora.	(A)

Enneapogon scoparius, E. brachystachyus, E. cenchroides and *Lepturella capensis* are pioneers typical of limestone soils (see Chapter 8, section 3).

Except *Cynodon dactylon* and *C. hirsutus,* these pioneers are of little grazing value. They are fairly well grazed when green in summer but disappear or become unpalatable afterwards and have a low carrying capacity. On fertile lands *Cynodon dactylon* is, however, a valuable, palatable and high yielding grass.

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* Common on both sandy loam and on turfy soils.
(P) = Perennial; (A) = Annual.

As has been shown by Louw (1951), the prostrate forms of the pioneer herbs are common on hard surfaced, bare areas, e.g. *Aristida* spp., *Tragus* spp., *Tribulus terrestris*. When these species are closely aggregated their shoots are usually erect. The following are the most common matted or prostrate pioneers of the area. They are listed more or less in order of abundance:—

Tribulus terrestris,	(A)
Alternanthera repens,	(A)
Atriplex semibaccata,	(P)
Gomphrena celosioides,	(P)
Limeum sulcatum,	(A)
L. viscosum,	(A)
Giesekia pharnaceoides,	(A)
Medicago denticulata,	(A) (also on heavy soils).
Euphorbia prostrata,	(A)
Listia heterophylla,	(P)
Hermannia depressa,	(A)
Euphorbia inaequilatera,	(A)
Helichrysum argyrosphaerum,	(P)
H. ericaefolium,	(P)
Harpagophytum procumbens,	(A)
Merremia verecunda,	(A)
Pelargonium fumarioides,	(P)
Blepharis integrifolia,	(P) (also on randjies).
Cassia mimosoides.	(P)

The species named below are erect or more or less erect. They are common as pioneers on bare hard-surfaced places in the veld and some of them may also be encountered on loose and disturbed soils. The following prefer heavy soils and are listed in order of abundance:—

Cyperus usitatus,	(A)
Cenia microglossa,	(A)
Delosperma malioni,	(P)
Hypertelis verrucosa,	(A)
Acalypha segetalis,	(A)
Phyllanthus maderaspatensis,	(P) and
Hibiscus trionum.	(A)

The following, all of which are perennials, are frequently found on sandy and sandy-loam soils. In order of abundance:—

Aster muricatus,
Salvia clandestina var. *angustifolia*,
Walafrida spp.,
Chrysocoma tenuifolia,
Bulbine asphodeloides,
Herniaria hirsuta,
Hermannia coccocarpa,
Indigofera alternans,

Pollichia campestris,
Solanum spp.,
Osteospermum muricatum,
Albuca pachychlamys, and
Schizocarpus nervosus.

2. ON FALLOW LANDS.

Where soil is disturbed by ploughing or any other means, the edaphic conditions are greatly altered. In ploughing the soil is left loose, has a high water absorptive capacity and is well aerated. Before the soil on fallow lands becomes compact again conditions differ greatly from those of denuded hard bare areas, and the vegetation during the first few years on fallow lands is easily distinguished from that on hard bare patches. When the soil on fallow lands becomes compact again the difference in the succession becomes less evident.

Unlike the colonisers of bare areas the pioneer plants on fallow lands are predominantly annuals and biennials. The erect forms are common and prostrate species are fewer than on the hard areas.

The succession was studied on lands at the Glen College of Agriculture, Camps No. Fx. 5 (6·9 morgen), No. M. 7 (20 morgen), No. D. 1 (40 morgen), and No. D. 2 (36 morgen) (see also map No. 1). The soil of these lands is a sandy loam and is, when left undisturbed, covered by Themeda. The last observations were made in April, 1953.

Occasionally a subsere on fallow lands may be dominated by a single species (see Louw 1951), but usually there are a few important species each represented by a large number of individuals.

The following pioneer grasses are common on all abandoned lands in this area. The species are listed in order of abundance:—

Aristida curvata,	(A)
Cliloris virgata,	(A)
Tragus racemosus,	(A)
Cynodon dactylon,	(P)
Aristida congesta,	(P)
Cynodon hirsutus, and	(P)
Eleusine indica.	(A)

The following species are often on old lands but are usually represented by a few individuals only:—

Urochloa panicoides,	(A)
Tragus berteronianus,	(A)
Eragrostis tef,	(A)
Setaria verticillata,	(A)
Aristida barbicollis,	(A)
Poa annua, and	(A)
Eragrostis biflora.	(A)

Panicum laevifolium which is an important pioneer in the higher rainfall area (25 inches to 35 inches) is almost absent from the area studied; a few tufts were found which were, however, restricted to moist depressions.

The following annual and perennial prostrate species are frequently found as pioneers on old lands in this area:—

Tribulus terrestris,	(A)
Convolvulus arvensis, and	(P)
Portulaca oleracea.	(A)

A multitude of exotic and indigenous weeds is present and in the following list the more common are given first. The list has been compiled from observations made on a number of lands scattered through the area investigated:—

Nidorella resedaefolia,	(A)
Salsola kali,	(A)
Chenopodium spp.,	(A)
Schkuhria bonariensis,	(A)
Erigeron canadense,	(A)
Argemone mexicana,	(A)
Amarantus spp.,	(A)
Atriplex suberecta,	(A to P)
A. semibaccata,	(P)
Papaver aculeatum,	(A)
Tagetes minuta,	(A)
Bidens pilosa,	(A)
Arctotis staechadifolia,	(A)
Berkheya onopordifolia,	(A)
B. epitrachys,	(A)
Datura spp.,	(A)
Cyperus spp.,	(A)
Asclepias fruticosa,	(P)
Salvia claudestina var. *angustifolia*,	(P)
Chrysocoma coma-aurea,	(P)
Physalis angulata,	(A)
Solanum nigrum,	(A)
Acrotome inflata,	(A)
Zinnia multiflora,	(A)
Lithospermum cinereum,	(P)
Flaveria contrayerba.	(A) etc.

A few of these pioneers, e.g. *Salsola kali*, *Nidorella resedaefolia*, *Argemone mexicana*, *Cyperus* spp., are also frequent on heavy soils. The white-flowered *Argemone mexicana* may dominate in spring on cultivated lands. The following are, however, the most characteristic and common pioneers and weeds on heavy turfy-clay soils; the species are listed in order of abundance:—

Sonchus oleraceus,	(A)
Cotula burchellii,	(A)
Senecio burchellii,	(A)
Cineraria lyrata,	(A)
Plantago spp.,	(P)

Cotula anthemoides,	(A)
Lepidium ruderale,	(A)
Crotalaria distans,	(A)
Lactuca dregeana,	(P)
Xanthium sp.	(A) etc.

The plant succession was studied on a few abandoned lands at the Glen College of Agriculture. The history and treatment of these abandoned lands is known so that the time required for the natural reoccupation of the sub-climax and climax vegetation can be given.

(*a*) *Land No.* M. 7 (20 *morgen*).

(1) *Northern Side.*—The soil of this land is a uniform red sandy loam. The land has a 3° to 5° south-eastern inclination towards the Middelwaterspruit, and is contoured at distances of 30 to 50 yards. Different grasses were planted between these contours. This land was cultivated for 25 years or more, was usually planted to maize and was left fallow for four years (1949 to 1952) before final observations were made. During the four years of fallowing the writer made regular observations on two morgen towards the northern side of the land. The following was noticed: During the first year after fallowing the annual pioneers and ruderals were most conspicuous, the most abundant types being:—

Salsola kali,
Tribulus terrestris, and
Nidorella resedaefolia.

The most important grasses were:—
Chloris virgata,
Tragus racemosus,
Eleusine indica,
Urochloa panicoides, and
Aristida curvata.

During the second year the cover became denser; all the above plants were present but *Aristida curvata* and *Eleusine indica* became prominent. *Tribulus terrestris*, *Nidorella resedaefolia* and *Urochloa panicoides* became less conspicuous. During the third year *Aristida curvata* and *Chloris virgata* were still predominating but the other pioneers were dying out, especially *Salsola kali*. The common pioneer *Cynodon dactylon* and a few tufts of *Eragrostis lehmanniana* were in patches. At the end of the fourth year the two last grasses became more prominent and the ruderals and annuals less conspicuous, occurring only here and there in smaller numbers. Although Themeda is dominant on some of the surrounding land no seedlings of this or other climax grasses were seen.

(2) *Southern Side.*—The succession was also studied on a small strip of land of one morgen, which forms a part of the land No. M. 7 (see map No. 2). This strip of land is towards the southern side of the land No. M. 7 and the adjoining veld consists principally of *Eragrostis lehmanniana* and Themeda.

It has been lying fallow for five years (1948 to 1952). During the first few years after fallowing, weeds and annuals were dominant. At the end of the fifth year the strip of land was surveyed and the following was found: The pioneers and weeds were almost totally replaced by the sub-climax *Eragrostis lehmanniana* which was dominant. Scattered here and there dense patches (1 to 3 feet in diameter) of *Cynodon dactylon* and *C. hirsutus* occurred. *Eragrostis obtusa* was found here and there, usually between the tufts of *E. lehmanniana*. On bare patches *Aster muricatus. Helichrysum ericaefolium* and *Atriplex semibaccata* were conspicuous. The dominance of *E. lehmanniana* within five years of fallowing can be ascribed chiefly to the seed which came from the adjoining *E. lehmanniana*-veld.

(*b*) *Camp No.* D. 3.

The succession was studied on an old land which had not been ploughed for approximately 15 years (1938 to 1952). This land of about 30 morgen forms the northern part of the camp No. D. 3 which is 70 morgen in extent (see map No. 2). The adjoining lands on the northern and southern sides are still under cultivation. On the east and west is Themeda-veld with much *Aster muricatus.* On the west a railway line separates this land from the adjoining Themeda-veld. As a result of heavy soil (which is unsuitable for cultivation under dry-land conditions) and the decline of yields, the 30 morgen part was abandoned in 1938 after 16 years of cultivation. During the past 15 years this fallow land has been rested in summer and grazed in winter. The ground has a slight southern inclination and two distinct soil types are found, i.e. a reddish-brown heavy loam and a red sandy loam. A marked difference in the vegetation could be observed on the two.

(1) *Reddish-brown Heavy Loam.*—This heavy soil is approximately 20 morgen in extent and occurs to the north and west of the land (see map No. 2). Regular observations were made and after a final survey on the 23rd and 24th April, 1953, the following was found: After approximately 15 years of fallowing the vegetation of the heavy soil in this old land is still in a pioneer stage. The vegetation consists of the following species which are listed in order of abundance:—

Chloris virgata,
Aristida curvata,
Cynodon dactylon,
Aristida congesta,
Cynodon hirsutus,
Chrysocoma tenuifolia,
Blepharis integrifolia,
Eragrostis lehmanniana,
Walafrida saxatilis,
Eragrostis obtusa,
E. chloromelas,
E. superba,
Panicum stapfianum, and
Themeda triandra.

The first two grasses dominate. The *Eragrostis* species mentioned must be considered as sub-climax grasses rather than pioneers. These sub-climax plants are, however, much more distantly scattered than on the adjoining sandy loam soil where they predominate. Two climax grasses, Themeda and *Panicum stapfianum* were found ocassionally on the heavy soil. They are often more conspicuous in the old ploughed furrows and in depressions.

Bare areas from one yard up to 20 yards in diameter occur rather frequently—probably as a result of poor surface water penetration. On the bare patches the prostrate *Blepharis integrifolia* and *Lotononis leobordea* and erect species like *Aster muricatus*, *Walafrida saxatilis* and *Chrysocoma tenuifolia* are the most conspicuous. Of the erect species *Aster muricatus* is the most abundant and is more conspicuous than *Walafrida saxatilis*. On small bare spots between the grass tufts *Chrysocoma tenuifolia*, *Walafrida saxatilis* and *Othonna pallens* occur but they are much less abundant than the grasses.

Although the soil fertility cannot be regarded as depleted the succession has proceeded very slowly and is still in a pioneer stage.

(2) *Sandy Loam Soil.*—As said, the sandy loam soil is in the south-east of the abandoned part of land No. D. 3 (see map No. 2). In the final survey made on 23rd and 24th April, 1953, the following species, which are listed more or less in order of abundance, were found:—

Eragrostis lehmanniana,
E. obtusa,
E. chloromelas,
Aristida curvata,
Chloris virgata,
Cynodon dactylon,
Aristida congesta,
Eragrostis superba,
Sporobolus fimbriatus,
Walafrida saxatilis,
Panicum stapfianum,
Themeda triandra,
Heteropogon contortus.

On this soil the sub-climax grasses *E. lehmanniana*, *E. obtusa* and *E. chloromelas* dominate. These grasses occur well intermixed and bare patches are insignificant. All over this land and especially in the south-east patches of the climax grasses Themeda and *Heteropogon contortus* are found scattered here and there and most conspicuous in depressions and in old plough furrows. The largest patch of Themeda is four yards in diameter. These patches are larger and spaced more closely than on heavy soil. *Panicum stapfianum* occurs as tufts scattered singly between the other grasses. Although commoner than on the heavy soil these climax grasses are still unimportant. As these patches are most abundant in the south-eastern part of this land it is assumed that the seeds enter from the adjoining Themeda-grassveld.

From these observations it is clear that the vegetation on the sandy loam soil has already reached the sub-climax stage while that on the heavier soil is still in the pioneer stage. Climax grasses have entered and are more abundant on the lighter than on the heavy soils. It is assumed that the physical condition of the soil and the water relations are the most important factors influencing the succession.

It will probably take many years before the sandy loam soil becomes dominated by Themeda. For the heavier soil the period to reach the climax in which *Panicum stapfianum* is expected to be common, will be much longer. On the heavy soils the pioneers will probably be succeeded directly by the climax grasses.

(*c*) *Camps Nos.* M. 9 *and* M. 10 (*see also map no.* 1).

These two camps are both 54 morgen in extent and were ploughed 25 years ago. The soil of these two camps is red sandy loam and has 2° inclination towards the Middelwaterspruit. Since these lands were laid fallow in 1928 they have been used for sheep grazing. Through the past six years camp No. M. 9 has been stocked at the annual rate of 1·3 morgen per sheep for five years and 25 morgen per sheep for the sixth year. Camp No. M. 10 has carried, through the past six years, one sheep per 2·1 morgen. Both camps were rested from 1 to 8 months per annum. The veld adjoining these camps consists principally of Themeda. These camps were regularly surveyed during the last four years and practically no changes were observed. With the final survey in April, 1953, the following conclusions were drawn: After the 25 years the vegetation is still in a pioneer-sub-climax stage with *Aristida congesta*, *A. curvata* and *Eragrostis lehmanniana* dominant. Other important grasses are *Eragrostis obtusa*, *E. superba*, *E. chloromelas* and *Cynodon* spp. Characteristic short-lived pioneers such as e.g. *Chloris virgata*, *Urochloa panicoides* and *Eleusine indica* are absent. Themeda and other climax grasses, e.g. *Heteropogon contortus* and *Sporobolus fimbriatus* occur in dense small patches here and there. The patches of the climax grasses are mostly found in damp hollows and old plough furrows where the moisture conditions are better. There is little indication that these patches are extending and if there is any extension, it is very slow. Shrubs and bushes are almost absent but on bare spots *Aster muricatus* dominates.

The old ploughed furrows are not yet all covered by Themeda, the succession is probably retarded by the absence of adequate seed supplies of the climax grasses. It is quite possible that soil fertility may also be a limiting factor.

CHAPTER 10.

FLORISTIC ANALYSIS AND ANNOTATED CHECK LIST OF THE PLANT SPECIES OCCURRING IN THE PARTS OF THE BLOEMFONTEIN AND BRANDFORT DISTRICTS STUDIED.

1. GENERAL ANALYSIS.

With the exception of a list of approximately 370 phanerogamic species compiled by Potts and Tidmarsh (1937), and included in their ecological study of the 18 square miles of Karroo-like vegetation directly north of Bloemfontein, no list of the flora of the Bloemfontein–Brandfort districts has been published.

Sporadic plant collections were made by the writer's predecessors at the Glen College of Agriculture. The present check list has been compiled principally from the plant collections made by the writer and from the herbarium of the University of the Orange Free State which contains specimens collected by various collectors. One of the most important being the late Dr. George Potts, Professor of Botany at the Bloemfontein University.

The specimens collected by the writer are in the herbarium of the Glen College of Agriculture. Exotic species which have established themselves permanently have been included in the list but sporadic escapes from cultivation have not.

This plant list is by no means exhaustive, nevertheless it contains the names of all the important and common species in the area. A large number of the species are common to the karroo also, especially in the families *Chenopodiaceae*, *Aizoaceae* and *Compositae*.

The floristic data of a number of botanical surveys which have been made in South Africa are given in Table 28.

If a floristic comparison of the different areas is made it should be remembered that no botanical list can be regarded as complete. As the species concept lacks uniformity [as intimated by Dyer (1937) and Louw (1951)], and varies with the age, it is certain that the numbers of genera and species given in Table 28 are not comparable. As Louw states, the tendency in recent years "has been to 'lump' species and to 'split' genera".

TABLE 28.—*Number of Phanerogamic Families, Genera and Species of the Bloemfontein–Brandfort Area and of Other Areas in South Africa.*

Area Studied.	Area, Square Miles.	Families.	Genera.	Species and Varieties.
South Western Region of the Cape, Bolus*	35,000	110	705	5,585
Cape Peninsula, Muir*	197	93	485	2,117
Flora of the Cape Peninsula, Adamson & Salter (1950)	182	115	668	2,559
Riversdale, Cape, Muir*	1,711	121	646	2,294
George, Knysna and Humansdorp, Phillips, J. F. V.*	6,000	119	613	2,185
Uitenhage and Port Elizabeth, Schönland*	4,000	129	716	2,312
George, Knysna, Humansdorp and Uniondale, Fourcade (1941)	5,429	131	831	3,130
Albany and Bathurst, Dyer (1937)	2,300	119	647	2,084
Keiskammahoek District, R. Story (1952)	220	?	287	+413
Natal and Zululand, Ex Muir from Bews*	29,000	148	901	3,786
Weenen County (Estcourt and Weenen), West (1949)	2,332	112	559	1,584
Springbok Flats, Galpin (1927)	4,550	84	203	584
Potchefstroom Area, Louw (1951)	1,750	95	477	1,016
Kroonstad, J. W. Pont (1932 to 1935)	?	67	295	510
Bloemfontein–Brandfort Area	1,000	78	415	978

* Taken from West (1949).

In Table 29 the number of species belonging to the major plant groups, i.e. the Spermatophyta and Pteridophyta, is given for the Bloemfontein–Brandfort area. In the order of numerical importance the families represented by more than 10 species and varieties are also indicated.

TABLE 29.

A.—MAJOR PLANT GROUPS REPRESENTED IN THE BLOEMFONTEIN–BRANDFORT AREA.

	Families.	Genera.	Species and Varieties.
Monocotyledonae	13	111	293
Dicotyledonae	65	304	685
TOTAL	78	415	978
Pteridophyta	4	8	11

B.—FAMILIES REPRESENTED BY MORE THAN 10 SPECIES.

Families.	Genera.	Species and Varieties.
Gramineae	55	145
Compositae	60	138
Leguminosae	23	71
Liliaceae	22	63
Scrophulariaceae	15	47
Cyperaceae	9	35
Aizoaceae	18	30
Cruciferae	9	25
Asclepiadaceae	14	25
Chenopodiaceae	5	23
Solanaceae	7	23
Amaryllidaceae	9	20
Convolvulaceae	6	19
Euphorbiaceae	4	18
Crassulaceae	4	16
Campanulaceae	5	15
Amarantaceae	6	13
Labiatae	7	12
Malvaceae	7	12
Caryophyllaceae	9	12
Iridaceae	6	11
Umbelliferae	10	11
Boraginaceae	8	11
Cucurbitaceae	6	10
Sterculiaceae	1	10

From Table 29 it can be seen that the *Gramineae*, *Compositae*, *Leguminosae* and *Liliaceae* are the four largest families, each with more than 60 species.

The number of species does not vary in direct proportion to the area and is determined to a large extent by topographic and climatic factors. As the area studied shows only slight variations in altitude and rainfall it is not very rich in species, especially if compared with areas surveyed in the Cape Province. If compared with other surveyed areas in the summer rainfall region of South Africa, however, it compares quite favourably (see Table 28). Interesting facts emerge with regard to the distribution of different plant families and species throughout the sub-continent.

In Table 30 a few plant families are compared. This comparison is made between the following areas: Bloemfontein–Brandfort, Potchefstroom, Weenen county and Kroonstad. All these fall in the summer rainfall region and, except for the Weenen county, form part of the great inland plateau. From Table 30 it is evident that the *Gramineae* are, except in Weenen county, the best represented. The second largest family is the *Compositae* (which is the largest in the Weenen county). The *Compositae* are generally followed by the *Leguminosae* and *Liliaceae*, which are the third and fourth largest families. The *Cyperaceae* and *Scrophulariaceae* are also well represented in the areas under consideration. The *Aizoaceae*, *Cruciferae*, *Solanaceae* and *Chenopodiaceae* are much better represented in the Bloemfontein-Brandfort than in the other areas. This is especially the case for the *Aizoaceae* and *Chenopodiaceae* which are typical Karroo families.

The *Crassulaceae* are also, with the exception of the Weenen county, better represented in the Bloemfontein–Brandfort districts than in the other areas compared. The family *Bignoniaceae* is represented by only one species (*Rhigozum obovatum*, also typical for the Karroo), and was not found in the other three areas. *Potamogetonaceae* are better represented in the Bloemfontein–Brandfort than in the Potchefstroom and Kroonstad areas and are absent from the Weenen county. The *Orchidaceae*, *Ericaceae* and *Capparidaceae* are quite well represented in the Weenen county. With the exception of the *Capparidaceae* these families are represented by fewer species in the Potchefstroom area. They are also poorly represented in or are absent from the Kroonstad flora. In the Bloemfontein–Brandfort area no *Ericaceae*, only one species of the *Capparidaceae* and only two species belonging to the *Orchidaceae* were found.

TABLE 30.—*Floristic Comparison of a few Selected Families in Four Areas occurring in the Summer Rainfall Region of South Africa.*

Area.	Bloemfontein–Brandfort.	Kroonstad.	Potchefstroom.	Weenen County.
Size in square miles.....	1,000	?	1,750	2,332
Families.	Number of Species.			
Gramineae.....	145	76	149	198
Compositae.....	138	73	126	242
Leguminosae.....	71	32	97	116
Liliaceae.....	63	37	51	74
Scrophulariaceae.....	47	12	36	59
Cyperaceae.....	35	14	50	65
Aizoaceae.....	30	17	4	10
Cruciferae.....	25	10	12	12
Solanaceae.....	23	18	15	15
Chenopodiaceae.....	23	5	6	7
Crassulaceae.....	16	7	10	21
Potamogetonaceae.....	4	2	1	0
Orchidaceae.....	2	3	8	34
Ericaceae.....	0	0	1	14
Bignoniaceae.....	1	0	0	0
Capparidaceae.....	1	1	6	6
Myrsinaceae.....	0	0	1	2

There is a great resemblance between the floras of the Bloemfontein–Brandfort, Potchefstroom and Kroonstad areas. A number of more tropical and sub-tropical families and species occurring in the Weenen county are absent from the Bloemfontein–Brandfort, the Potchefstroom and Kroonstad areas. Sub-tropical genera like Pappea, Combretum and Maerua occur in the Potchefstroom area but are absent from the Bloemfontein–Brandfort area.

2. CHECK LIST.

Plant species marked with an x were not found or collected by the author but records were taken from the herbarium of the University of the Orange Free State; the name of the collector, Bloemfontein University herbarium number and the year collected (in brackets), are indicated. The rest of the plants are in the herbarium of the Glen College of Agriculture; with unidentified species the writer's number is given.

PTERIDOPHYTA.

Marsileaceae.

x *Marsilea burchellii* (Kunze) A.Br. G. Potts, 1444. (1908).

x *M.* sp. prob. *M. macrocarpa* Pr. Grows in protected shady pools in vleis. J. Hatchard, 3791. (1925).

x *M.* sp. Found in a pool near Bfn. G. Potts, 1237. (1915).

Polypodiaceae.

x *Asplenium aethiopicum* (Burm.) Bediener. Grows in shade of boulders on hill slopes near Bfn. G. Potts, 2195. (1915).

Ceterach cordatum (Thunb.) Desv. Grows in shade of boulders on randjie slopes. Fairly common.

Cheilanthes hirta Sw. Common on randjie slopes.

Notholaena eckloniana Kunze. Occurs in shelter of boulders on randjies.

Pellaea calomelanos (Sw.) Link. Common on randjies.

x *P. viridis* (Forsk.) Pr. var. *glauca* Sim. Recorded from Bfn. G. Potts, 1374.

Ophioglossaceae.

x *Ophioglossum sarcophyllum* Desv. Grows in short open grassveld on low-lying sandy soil at Shannon. G. Potts, 3473. (1925).

Equisetales.

Equisetum ramosissimum Desf. Common on sandy banks in the Modder River.

SPERMATOPHYTA.

MONOCOTYLEDONEAE.

Typhaceae.

Typha australis Schum. & Thonn. Hydrophyte.

Potamogetonaceae.

Potamogeton crispus L. Rare, aquatic herb.

P. nodosus Poir. Common floating aquatic.

P. pusillus L. Aquatic herb. Occurs frequently.

x *Zannichellia palustris* L. Submerged hydrophyte occurring in dams in the Kaalspruit and in the Modder River. V. A. Wager, 3639. (1926).

Aponogetonaceae.

x *Aponogeton* sp. Aquatic herb. Uncommon. G. Potts, 3472. (1925).

Hydrocharitaceae.

Lagarosiphon muscoides Harv. Submerged or floating aquatic herb.

Gramineae.

Imperata cylindrica (L.) Beauv. Perennial. Leaf-tips are spinescent.

Hemarthria altissima (Poir.) Stapf. and Hubb. (= *H. fasciculata* Kunth.) Common hygrophilous species.

Elyonurus argenteus Nees. Sourgrass.

Andropogon appendiculatus Nees. Broad-leaved grass.

Sorghum verticilliflorum Stapf. Troublesome annual rhizomatous weed in lands under cultivation.

Dichanthium aristatum (Poir.). C. E. Hubb. Occurs on old lands, Glen. Very rare.

Cymbopogon excavatus (Hochst.) Stapf. Unpalatable grass.

C. marginatus Stapf. Locally rather rare.

C. plurinodis Stapf. Intermixed with Themeda on the bults.

Hyparrhenia glauca Stent. A few plants were found on the edge of a dry flush at Glen.

H. hirta (L.) Stapf. Restricted to randjies.

Heteropogon contortus (L.) Beauv. Common in Themeda-veld.

Themeda triandra Forsk. Most common climax grass.

Anthephora pubescens Nees. Common erect grass.

Tragus berteronianus Schult. Annual pioneer.

T. koelerioides Asch. Common creeping pioneer.

T. racemosus (L.) All. Common annual pioneer.

Paspalum dilatatum Poir. Introduced species.

P. distichum L. Hygrophilous, abundant.

Eriochloa fouchei Stent. Robust annual.

Panicum coloratum L. Leafy, stoloniferous.

P. deustum Thunb. Tall hygrophilous species.

x *P. glabrescens* Steud. (= *P. longijubatum* Stapf.). Erect species growing in a dam near Bfn. G. Potts, 1329.

P. laevifolium Hack. Annual species restricted to wet lands.

P. maximum Jacq. Occurs on the banks of the Modder River, etc.

P. stapfianum Fourc. (= *P. minus* var. *planifolium* Stapf.). Common on heavy soils.

P. sp. Uncommon prostrate annual, restricted to water furrows and depressions on sandy soils near Glen. No. 353.

Urochloa panicoides Beauv. (= *U. helopus* Stapf.). Annual pioneer.

U. pullulans Stapf. Leafy perennial.

Brachiaria eruciformis (Sibeth *et* Smith) Griseb. [= *B. isachne* (Roth.) Stapf.]. Common annual.

B. marlothii (Hack.) Stapf. Annual weed frequently found in gardens. In competition it grows erect but on open situations it is prostrate, rooting at the nodes.

B. serrata (Spreng.) Stapf. Leafy perennial occurring on randjies.

Echinochloa colona Link. Hygrophilous annual.

E. crus-galli (L.) Beauv. Hygrophilous pioneer.

E. holubii (Stapf.) Stapf. Robust perennial.

E. stagnina Beauv. Erect stoloniferous grass.

x *Digitaria argyrograpta* (Nees) Stapf. Soft-leaved species occurring in Themeda-veld and on old lands near Bloemfontein. G. Potts, 2396. (1917).

D. eriantha Steud. Common in grassveld.

D. monodactyla (Nees) Stapf. Occurs in Themeda grassveld.

D. sanguinalis (L.) Scop. Annual weed in lands and gardens.

D. ternata (Hochst.) Stapf. Fairly frequent pioneer in lands, gardens and disturbed sites.

Rhynchelytrum repens (Willd.) Hubb. (= *R. roseum* Stapf. and Hubb.). Scattered on randjies.

R. setifolium (Stapf.) Chiov. Occurs singly on the summit of hills and koppies.

Setaria flabellata Stapf. Stoloniferous, common in Themeda-veld.

S. imberbis R. & S. Favours wet situations. Uncommon.

S. nigrirostris (Nees) Dur. & Schinz. Abundant on heavy soils.

S. pallidifusca (Schum.) Stapf & Hubb. Occasional in wet vleis and lands.

x *S. sphacelata* (Schum.) Stapf. & Hubb. (= *S. aurea* A. Braun). Occurs in shallow watercourses near Bfn. Spread by underground shoots. G. Potts, 2418. (1917).

S. verticillata (L.) Beauv. Common annual weed in gardens.

x *S. woodii* Hack. (= *S. gerrardi* Stapf.). Found between rocks in exposed parts of a kloof near Bfn. A. Lyle, S. 233. (1927).

Cenchrus ciliaris L. Perennial grass.

Pennisetum sphacelatum (Nees) Dur. & Schinz. Occurs on stream edges.

Ehrharta panicea Sm. (= *E. erecta* Lam.). Sciophilous winter grass. Occasionally found on cool southern randjie-slopes.

Phalaris arundinacea L. var. *picta* L. Hygrophilous, grows on edges of pools near Bfn.

P. minor Retz. Annual weed in lands. Rather rare.

Aristida barbicollis Trin. & Rupr. Ruderal on disturbed ground. Rather rare.

A. bipartita (Nees) Trin. & Rupr. Locally abundant on heavy soils.

A. canescens Henrard. Frequent on hills.

A. congesta R. & S. Pioneer on old lands and distrubed ground.

A. curvata (Nees) Trin. & Rupr. Common annual pioneer.

x *A. diffusa* Trin. var. *burkei* (Stapf.) Schweick. Erect hardy grass, collected at Glen. V. A. Wager, 3727. (1926).

A. graciliflora Pilg. Common pioneer on sandy soil in the western part of this area.

A. junciformis Trin. & Rupr. Locally rather rare.

A. scabrivalvis Hack. Occasional as a pioneer in denuded camps.

A. uniplumis Licht. Perennial.

A. uniplumis (Licht.) var. *neesii* Trin. & Rupr. Robust, 1 to 3 feet high.

A. vestita Thunb. Common grass.

Sporobolus argutus (Nees) Kunth. Ruderal. Occurs on heavy soil along the Modder River.

S. discosporus Nees. Very small species occurring in Themeda-veld. Rare.

S. fimbriatus Nees. Common in Themeda-veld.

S. iocladus Nees. Perennial. Favours heavy soil.

S. ludwigii Hochst. Frequent on heavy soils.

x *S. parvulus* Stent. Small, 3 to 4 inches high. Recorded from Bfn. G. Potts, 4612. (1931).

S. tenellus Kunth. Short matted species.

x *Agrostis griquensis* Stapf. Small grass growing on damp ground near running water at Bfn. G. Potts, 2470. (1917).

A. lachnantha Nees. Common hygrophilous species.

A. semiverticillata (Forsk.) C. Christ. (= *A. verticillata* Vill.). Perennial, matted.

Helictotrichon turgidulum (Stapf.) Schweick. Occurs in vleis.

x *Pentaschistis airoides* Stapf. Pioneer in veld at Bfn., collected by a native John Moraile, 4528. (1929).

Microchloa caffra Nees (= *M. abyssinica* Hochst.). Small grass.

Cynodon dactylon Pers. Abundant as a pioneer.

C. hirsutus Stent. Common pioneer.

x *C. incompletus* Nees. Short, creeping, occurs in open grassveld. G. Potts, 4547. (1930).

C. transvaalensis Burtt-Davy. A short lawn grass forming dense mats on sides of pans and vleis at Saltpan.

Chloris gayana Kunth. Cultivated grass which is spreading as an escape at the wet sides of lands and plots at Glen.

C. virgata Swartz. Most common ruderal.

Eustachys paspaloides (Vahl.) Lanza & Matti. Locally frequent on hills, etc.

Tetrachne dregei Nees. Rare palatable grass.

Eleusine indica (L.) Gaertn. Common ruderal of cultivation.

Enneapogon brachystachyus (Jaub. *et* Spach.) Stapf. Characteristic pioneer on limestone soils.

E. cenchroides (Licht.) C. E. Hubb. Robust pioneer.

E. scoparius Stapf. Dominating on limestone soils.

Triraphis andropogonoides (Steud.) Phillips. Stiff perennial, occasionally found on bults.

Tristachya rehmanni Hack. Collected on a flat stony ridge near Glen. Uncommon and unpalatable.

Fingerhuthia africana Lehm. Frequent on limestone soils.

Phragmites communis Trin. Common hygrophilous species.

Diplachne fusca (L.) Beauv. Common hygrophilous grass.

D. fusca (L.) Beauv. var. *stolonifera* Goossens. Perennial, prostrate and rooting at the nodes.

Pogonarthria squarrosa (Licht.) Pilger. (= *P. falcata* Rendle). Hardy grass growing on lower slopes of hills and on bults.

Trichoneura grandiglumis (Rendle) Stapf. & Hubb. Pioneer on disturbed sites.

Eragrostis atherstonei Stapf. Occurs on hills.

E. barbinoides Hack. Broad-leaved tufted perennial. Rather rare.

E. barrelieri Dav. Annual weed in gardens and lands. Quite common.

E. bicolor Nees. Frequent on heavy soils.

E. biflora Hack. Common annual in gardens and wet shady situations.

E. chloromelas Steud. Common on the flats, vleis and bults.

E. cilianensis (All.) Link. (= *E. major* Host.). Weed in gardens, rare.

E. curvula Nees. Valuable strongly-tufted grass.

E. curvula Nees var. Fine-leaved, 6 to 12 inches tall. Occurs on over-grazed situations in the valleys. No. 410.

E. curvula Nees var. Broad-leaved, strongly tufted. Occasional on heavy soils. No. 369.

E. curvula Nees var. *conferta* Nees. Rare.

E. denudata Hack. Grows between stones on koppies and limestone out-crops.

E. gummiflua Nees. Hardy perennial. Rather rare.

E. hygrophila Hubb. & Schw. Annual, grows on bed of dams and furrows.

E. lehmanniana Nees. Most common species.

E. lehmanniana Nees var. *ampla* Stapf. Stoloniferous. Few plants were found on an old maize land near Glen.

x *E. margaritacea* Stapf. Tall coarse grass. Grows in marshy soils at Bfn. G. Potts, 2521. (1917).

E. micrantha Hack. Occurs in wet situations.

E. nebulosa Stapf. Robust viviparous species.

E. obtusa Munro. Common perennial.

x *E. pilosa* (L.) Beauv. Probably and annual growing on marshy soil near Bfn. G. Potts, 2522. (1917).

E. plana Nees. Occasional on wet situations.

E. porosa Nees. Prostrate pioneer rooting at the nodes.

x *E. procumbens* Nees. Annual weed, grows on roads, etc. G. Potts, 2529. (1917).

E. superba Peyr. Widely scattered in Themeda-veld.

E. tef (Zucc.) Trott. (= *E. abyssinica* Schrad). Annual in lands and gardens.

E. truncata Hack. Grows on koppies, etc.

E. sp. Broad-leaved. Scattered singly on edges of water furrows at Glen. Nos. 243 and 742.

Melica decumbens Thunb. Sciophilous grass.

M. racemosa Thunb. Common sciophilous species.

Briza minor L. Annual, rare, occurs in gardens.

Lasiochloa longifolia Kunth. Rare annual, occurring in gardens.

Schismus barbatus A. Chase (= *S. fasiculatus* Beauv.). Annual winter-weed growing in lands and gardens.

Poa annua L. Annual winter-grass.

Bromus catharticus Vahl. Locally abundant in cool and moist situations.

B. japonicus Thunb. Winter-weed in gardens, etc.

B. rigidus Roth. (= *B. maximus* Desf.). Annual winter-weed. Grows in shady situations.

B. speciosus Nees. A few plants were found in a garden at Glen.

Lolium multiflorum Lam. Acclimatised introduced grass.

L. temulentum L. Winter annual. Occurs rarely in cultivated lands.

Lepturella capensis Stapf. Small pioneer.

Hordeum chilense Brogn. var. *compressum* (Gris.) Hauman. Alien species.

H. murinum L. Rare annual, grows on sides of irrigated lands, Glen.

H. nodosum L. (= *H. secalinum* Schreb.). Uncommon winter-weed in gardens, Glen.

Elymus sp. Acclimatised introduced grass. No. 263.

Cyperaceae.

x *Cyperus bellus* Kunth. Annual sedge occurring amongst boulders on a hill near Bfn. G. Potts, 1923. (1915).

C. compactus Lam. Associated with grasses on flats and plains. Occasional.

C. sp. nr. *C. compressus* L. Common weed on wet sides of Mockesdam. No. 800.

C. difformis L. Annual, occasionally found in wet vleis and other situations.

C. esculentus L. Weed in cultivated lands.

C. longus L. Found in streams.

C. marginatus Thunb. Most abundant sedge.

x *C. margaritaceus* Vahl. Recorded from Glen; probably in grassveld. V. A. Wager, 3728. (1926).

C. textilis Thunb. Robust sedge occasionally found at margins of pools.

C. usitatus Burch. Common sedge.

C. sp. Robust sedge. No. 675.

x *Mariscus aristatus* Rottb. (= *Cyperus aristatus* Rottb.). Dense, tufted, 3 to 4 inches high. Occurs in pools. G. Potts, 1924. (1915).

M. capensis Schrad. Frequent in Themeda-veld.

M. congestus. C.B.CI. Three to four feet tall.

x *M. rehmannianus* C.B.CI. Probably annual. Occurs on koppies. G. Potts, 3016. (1917).

M. sp. Occassionally in grassveld on bults. No. 764.

Kyllinga alba Nees. Widely scattered in Themeda grassveld.

x *K. alba* Nees var. *alata* C.B.CI. Occurs amongst grasses on a dry habitat near Bfn. G. Potts, 3000. (1917).

x *K. erecta* Schum. Rhizomatous, grows on the outer region of a pan near Bfn. G. Potts, 3006. (1917).

x *Ficinia* sp. Probably an annual occurring in a large pan near Bfn. G. Potts, 1076. (1915).

x *Scirpus burkei* C.B.CI. Occurs on low-lying dry spots north of Bfn. G. Potts, 3010. (1917).

S. dioecus Boeck. Hygrophilous sedge.

S. fluitans L. Small matted perennial.

x *S. hystrix* Thunb. Small annual. Uncommon. Found on marshy soils. G. Potts, 2349. (1917).

x *S. lacustris* L. Recorded from a pool in Bfn. G. Potts, 1926. (1915).

x *S. muricinux* C.B.Cl. (probably). Rare. Occurs on marshy ground along the Petrusburg road near Bloemfontein. G. Potts, 3003. (1917).

x *S. nodosus* Rottb. Grows on red, sandy soil at Bainsvlei, near Bloemfontein. G. Potts, 1081. (1915).

x *S. setaceus* L. Small, densely tufted. Occurs at sides of watercourses. G. Potts, 3024. (1917).

x *S. paludicola* Kunth. Recorded at the Dewetsdorp road near Bloemfontein. G. Potts, 1096. (1915).

S. sp. Frequent on moist sites. Nos. 23 and 382.

Eleocharis palustris R. Br. Hygrophilous, forms dense mats in wet situations.

x *Bulbostylis humilis* Kunth. Small slender-leaved sedge occurring on low koppies north of Bfn. G. Potts, 3007, 2420. (1917).

Schoenoxiphium kunthianum Kuk. Abundant on southern slopes of randjies, 10 miles east of Glen.

Carex vulpina L. (= *C. glomerata* Thunb.). Has grass-like leaves. Hygrophilous.

C. sp. Robust, hygrophilous, 3 to 5 feet tall. No. 625.

Lemnaceae.

Lemna minor L. Minute floating aquatic.

Commelinaceae.

Commelina africana L. Yellow-flowered herb.

C. benghalensis L. Blue-flowered herb. Occasional in grassveld.

x *C. karooica* C.B.Cl. Yellow-flowered herb. Recorded from red sandy soil near the Dealesville–Bloemfontein road. G. Potts, 397. (1907).

Juncaceae.

Juncus arabicus Adamson. Uncommon sedge.

J. effusus L. Forms dense patches in the bed of the Modder River.

J. exsertus Buch. Hygrophilous, common.

J. krausii Hochst. (= *J. maritimus* Lam.). Grows on sandy soils northwest of Bloemfontein, leaves with hard sharp points. G. Potts, 1078. (1915).

J. punctorius L. Stoloniferous, occasionally found in the bed of the Modder River.

J. rupestris Kunth. Annual grass-like rush, forms tufts on damp ground.

Liliaceae.

Androcymbium burkei Bak. Small geophyte. Found in Themeda-veld, five miles S.W. of Glen. Very rare.

A. melanthioides Willd. Small geophyte.

x *A. melanthioides* Willd. var. *acaule* Bak. Occasional in grassveld near Bfn. V. C. Green, 5448. (1943).

x *A.* sp. Leaves appr. one inch broad at the base and six inches long. Recorded from Bfn. G. Potts, 3283. (1924).

Bulbine asphodeloides R. & S. Different varieties were recorded.

B. caespitosa Bak. Frequent on bare soils in the Modder River valley.

B. sp. cf. *B. annua* Willd. Recorded from the Rhenosterspruit.

x *B.* sp. cf. *B. narcissifolia* Salm Dyck. Recorded from the banks of the Rhenosterspruit. G. Potts, 2802. (1917).

B. robusta var. Frequent on overgrazed situations in the Modder River. No. 43.

x *Anthericum campestre* Moss. Occurs amongst grasses in Themeda-veld. G. Potts, 2803. (1917).

A. macowani Bak. Frequent on open spots between grasses in the valleys.

A. paniculatum Moss ms. Sparsely scattered on stony situations.

A. pulchellum (Bak). Moss ms. Widely scattered in Themeda grassveld.

A. trichophyllum Moss ms. Widely spread in Themeda-veld.

Schizobasis cuscutoides (Burch.) Benth. Chasmophyte.

Eriospermum corymbosum Bak. Small herb.

Kniphofia ensifolia Bak. var. *tuckii* (Bak.) Bruce (= *K. tuckii* Bak.). Robust, 2 to 3 feet high.

Aloe grandidentata Salm Dyck. Grows on hills.

A. sp. cf. *A. grandidentata* Salm Dyck x *A. claviflora* Burch. According to Nat. Herb. Pretoria, this species is probably the above cross, as its anthers are too pronounced for *A. grandidentata.* Forms dense clans on hill slopes. No. 542.

x *Chortolirion subspicatum* (Bak.) Berger. Occurs on ironstone koppies. Leaves spirally twisted. G. Potts, 1478. (1916).

Tulbaghia acutiloba Harv. Abundant in the Modder River valley.

T. leucantha Bak. Frequent in the Modder River valley.

Albuca pachychlamys Bak. Common pioneer.

A. setosa Jacq. Robust, spring flowering, frequently scattered on hill slopes.

A. tenuifolia Bak. Widely scattered.

x *A. trichophylla* Bak. Yellow-flowered with green stripes on each petal. Occurs at Bfn. D. M. Gemmell, 5079. (1931).

A. sp. Tender small plant, 2 to 3 inches high. No. 128.

Thuranthos sp. (= *Urginea basutica* Phill.) A plant occurring on heavy soils.

Urginea langii Brem. Erect geophyte.

U. sp. nr. *U. langii* Brem. Pioneer on denuded heavy soils. No. 201.

Urginea sp. Slender-stemmed plant, 1 to 2 feet high. One leaf which appears after flowering. No. 196.

x *Drimia angustifolia* Bak. Grows in pools where water stands after rains Bfn. G. Potts, 1525. (1916).

D. ciliaris Jacq. Erect geophyte. Leaves appear after the flowers.

x *D. elata* Jacq. Grows on low ground near the Rhenosterspruit. Leaves produced after the flowers. G. Potts, 1052. (1915).

D. sp. Appears in well managed Themeda-veld. Leaves are spirally twisted. No. 713.

Rhadamanthus sp. Small, 2 to 3 inches high. Leaves produced after the flowers. No. 720.

Dipcadi ciliare (E. and Z. *ex* Harv.) Bak. Rare, grows in Themeda and Valley grassveld.

D. elatum Bak. Strong plant 2 to 3 feet high. Occasional on disturbed sites near kraals, etc.

D. gracillinum Bak. Fine-leaved plant forming dense stands on fertile soils on the lower slopes of hills and rises.

x *D. brevifolium* (Thunb.) Fourcade [= *D. hyacinthoides* (Spreng.) Bak.]. Occurs on shallow soil overlying rock on randjies north of Bfn. G. Potts, 1489. (1916).

D. viride Moench. Common pioneer.

D. sp. prob. *D. viride* Moench. Slender-stemmed and fine-leaved species occasionally found as a constituent of undergrowth under trees in the valley of the Modder River. No. 685.

x *Scilla* sp. cf. *S. lanceaefolia* (Jacq.) Bak. Grows on " brackish " soils near the Rhenostersprui. G. Potts, 2862. (1917).

x *S. macowani* Bak. Small, purplish-flowered, grows on koppies north of Bfn. G. Potts, 5251. (1927).

S. pusilla Bak. Frequently scattered on fertile soils at the foot of krantze and also in the valleys.

Schizocarpus nervosus (Burch.) F. v. d. M. (= *Scilla rigidifolia* Burch.). Grows in denuded bult grassveld.

Eucomis amaryllidifolia Bak. Grows on southern hill slopes. Rare.

E. undulata Ait. Occurs on heavy soils.

Ornithogalum sp. cf. *O. graminifolium* Thunb. Tree undergrowth in the Modder River valley.

O. prasinum Lindl. Common on heavy soils.

O. pretoriense Bak. Occurs in overgrazed Themeda-veld.

O. setifolium Kunth. Less frequent on lower hill slopes.

Neobakeria comata (Bak.) Schlecht. Rare.

Massonia greenii Bak. Grows on randjie slopes.

M. latifolia L. f. Small winter-plant.

x *Asparagus africanus* Lam. Erect shrub growing on ironstone koppies near Bfn. G. Potts, 1479. (1916).

A. laricinus Burch. Common in local valleys.

A. medeoloides Thunb. Grows on hill slopes.

x *A. microrhaphis* Bak. Thorny shrub, 3 to 4 feet high. Grows in the shade of trees. G. Potts, 848. (1915).

A. rivalis (Burch.) Kies. Grows on rocky situations and also in valleys.

A. stipulaceus Lam. Shrub up to two feet high. Grows on koppies north of Bfn.

A. suaveolens Burch. Common on randjies.

x *A.* sp. Shrub 2 to 3 feet high. Occurs on rocky ground near Bfn. G. Potts, 3715. (1927).

Amaryllidaceae.

x *Hessea filifolia* Benth. Grows rarely on the slopes of randjies near Bfn. White-flowered. G. Potts, 2876. (1917).

H. sp. nov. White-flowered and six inches tall. Abundant on overgrazed summit of a low stony koppie near Sannaspost in the south-eastern side of the area studied. No. 807.

Haemanthus amarylloides Jacq. Very common in the valleys.

H. sp. prob. *H. carneus* Gawl. Restricted to shady spots at base of boulders on hill slopes. Frequent.

H. hirsutus Bak. Common in sheltered parts of kloofs near Bfn.

Boöphone (*Buphane*) *disticha* (L. f.) Herb.

x *B.* sp. prob. *B. disticha* (L. f.) Herb. Recorded from a koppie near Bfn. G. Potts, 3431. (1924).

Nerine laticoma (Ker.) Dur. & Schinz. Sparsely scattered in the Modder River valley.

x *N.* sp. nr. *N. laticoma* (Ker.) Dur. & Schinz (= *N.* sp. nr. *N. lucida* Herb.). Occurs amongst grasses on koppies. C. E. Tidmarsh, 5118. (1934).

x *Brunsvigia radulosa* Herb. Recorded from Bfn. Leaves produced after the flowers. G. Potts, 834. (1908).

Gethyllis sp. nov. Occurs on sandy soil near Merino, 10 miles west of Glen. Pink-flowered and sweetly scented.

Crinum bulbispermum (Burm.) Milne Redhead & Schweick. Robust, scattered along watercourses.

Ammocharis coranica (Ker. Gawl.) Herb. [= *A. falcata* (Jacq.) Herb.]. Occurs on heavy soils.

Hypoxis angustifolia Lam. Occasional in grassveld.

x *H. argentea* Harv. Occasionally found on the banks of watercourses. C. E. Tidmarsh, 5117. (No date).

H. argentea Harv. var. *sericea* (Bak.) Harv. Common in grassveld towards the eastern part of this area.

H. longifolia Bak. Scattered singly on hill slopes.

x *H.* sp. cf. *H. hemerocallidea* Fisch. & Mey. Leaves covered with long white hairs so that the whole plant has a woolly appearance. Occurs on hills. John Moraille, 3518. (1924).

H. rigidula Bak. Occurs on Randjie slopes at Glen. Rather rare.

H. rooperi Moore. Occasional in Themeda grassveld and on hill slopes.

Iridaceae.

Moraea polystachya Ker. Widely scattered.

x *M.* sp. prob. *M. tenuis* (R. & S.) Ker. Recorded from Bfn. G. Potts, 1438. (1908).

Gynandriris simulans Bak. (= *Moraea simulans* Bak.). Scattered in valleys and vleis.

x *Homeria aurantiacea* Sweet. Recorded from Bfn. Collected by Potts and Tidmarsh. (No date).

x *H. pallida* Bak. Grows at the foot of koppies north of Bfn. J. C. Bidwell, 3786. (1925).

H. pura N.E. Br. Common tulp.

x *Babiana bainesii* Bak. Recorded from Bfn. G. Potts, 1378, Miss Hawkins, 2159. (1909).

B. hypogaea Burch. Common on sandy soils.

Gladiolus edulis Burch. Tall erect species.

x *Lapeyrousia caespitosa* Bak. Found on the race-course in Bfn. G. Potts, 2156. (1909).

L. galaxoides Bak. Small species.

Orchidaceae.

x *Habenaria foliosa* Reichb. f. (= *Habenaria polyphylla* Kranzl.) Recorded from Bfn. Mr. Leith, 774. (1907).

x *Bonatea speciosa* Willd. (= *Habenaria bonatea* Reichb. f.). Grows on ironstone hills amongst low shrubs. Very rare. J. D. Kestell, 3986. (1929).

DICOTYLEDONAE.

Salicaceae.

Salix babylonica L. Exotic tree.

S. capensis Thunb. Common riparian tree.

Ulmaceae.

Celtis africana Burm. f. (= *C. kraussiana* Bernh. & *C. rhamnifolia* Presl.). Tree attaining a height of 30 feet.

x *Urtica dioica* L. Grows in shade of a hedge on irrigated ground near Bfn. G. Potts, 3571. (1925).

Loranthaceae.

Viscum rotundifolium Thunb. Parasite on trees and shrubs.

Santalaceae.

Osyris compressa (Berg) A.DC. (= *O. abyssinica* Hochst.). Evergreen shrub.

x *Thesium confine* Sond. Root parasite, growing beneath shrubs and trees. Trailing. G. Potts, 76. (1906).

T. deceptum N.E. Br. Thick-rooted herb, singly scattered in valleys of watercourses. It was not found as a parasite.

T. racemosum Bernh. Perennial herb, growing amongst grasses in Themeda-veld. Rare. It was not found as a parasite.

Polygonaceae.

Emex australis Steinh. Annual prostrate weed of cultivation.

Rumex lanceolatus Thunb. (= *Rumex ecklonianus* Meisn.). Hygrophilous weed.

x *Polygonum amphibium* L. Grows in water in the Rhenosterspruit. Long branches and leaves floating on the water surface and rooted at the base in the mud. G. Potts, 3287. (1917).

P. aviculare L. Common in moist situations.

P. convolvulus L. Perennial scandent herb.

P. lapathifolium L. Grows at dam edges, etc.

P. lapathifolium L. var. *glabrum* B. Davy. Common.

P. plebium R. Br. Abundant in wet situations.

Chenopodiaceae.

Chenopodium album L. Common weed.

C. ambrosioides L. Aromatic herb frequently found on disturbed parts of the area.

C. foetidum Schrad. Annual weed.

C. glaucum L. Pioneer.

C. glaucum L. s. sp. *marlothianum* (Murr.) Thell. & Aellen. Annual prostrate weed in gardens.

C. mucronatum Thunb. Grows on disturbed " brackish " soils.

C. multifidum L. [= *Roubieva multifida* (L.) Moq.]. Prostrate annual weed or pioneer on disturbed soil.

C. murale L. Common pioneer and weed. Parts of the leaves are often dark-red coloured.

C. sp. nr. *C. botrys* L. Grows in shade of trees and boulders on hill slopes. No. 838.

C. sp. nr. *C. boutei* Aellen. Prostrate annual, found rarely in gardens. No. 361.

Exomis microphyllum (Thunb.) Aellen (= *E. axyrioides* Fenzl.). Perennial aromatic herb. Pioneer on waste places.

Atriplex erosa Verdoorn M S. (= *A. rosea* L.). Annual broad-leaved herb.

A. muelleri Benth. Annual broad-leaved herb. Abundant on disturbed, overgrazed and cultivated situations.

A. semibaccata R. Br. Well known exotic species.

A. semibaccata R. Br. var. Prostrate shrublet. Pioneer.

A. suberecta Verdoorn M S. Shrublet, abundant on bare situations.

Atriplex vestita (Thunb.) Aellen (= *Atriplex capensis* Moq. & *A. halimus* L.). Occurs on " brackish " soils in the Modder River valley. Uncommon.

Blackiella inflata (F. v. d. M.) Aellen (= *Atriplex inflata* F. v. d. M. and *A. halimoides* Lindl.). Sparsely scattered on " brackish " soils near the Modder River.

x *Salsola aphylla* L. f. Robust shrub favouring " brackish " soils in the Modder River valley, Glen. G. Potts, 2756, 2757. (1922).

x *S. foetida* Del. Erect shrub, two feet high. Rare in the Modder River valley. G. Potts, 2573. (1917).

S. glabrescens B. Davy. Common shrub on heavy soil.

S. kali L. Common annual pioneer.

S. nigrescens Verdoorn. Frequent in the Modder River valley.

Amarantaceae.

x *Amarantus angustifolius* Lam. (= *A. blitum* L.). Erect herb recorded from Bfn. G. Potts, 2579. (1917).

A. caudatus L. var. Introduced weed found in gardens.

A. deflexus L. Annual weed on distrubed places.

A. muricatus Gill. Annual, decumbent and hygrophilous.

A. paniculatus L. Common weed of cultivation.

A. thunbergii Moq. Annual hygrophilous weed. Leaves cooked as greens by natives.

Sericorema remotiflora (Moq.) Lopr. Frequent on stony bults.

Pupalia lappacea Juss. Erect herb occurring not very abundantly on rocky soil in the shade of bushes on koppies.

Achyranthes aspera L. Herb, favouring shady moist situations.

Alternanthera nodiflora R. Br. Occasionally found in wet vleis and stony bed of streams.

A. repens (L.) O. Ktze. (= *A. echinata* Smith). Important pioneer.

Gomphrena celosioides V. Mart. (= *G. decumbens* Jacq. var.). Decumbent pioneer.

x *Brayulinea densa* Willd. Forms dense mats, approximately two inches in diameter on roadsides. D. M. Gemmell, 6358. (1953).

Nyctaginaceae.

Commicarpus pentandra (Burch.) Feimerl. (= *Boerhaavia pentandra* Burch.). Prostrate herb.

C. sp. nr. *C. adscendens* Willd. Prostrate perennial pioneer. Rare. Occurs on bare situations. No. 399.

Phytolaccaceae.

Limeum aethiopicum Burm. Occurs in the shade of Acacia trees. Rare.

L. sulcatum Hutch. (= *L. linifolium* Fenzl.). Common pioneer.

L. viscosum Fenzl. Prostrate herb.

Giesekia pharnaceoides L. Annual herb. Pioneer.

Aizoaceae.

Mollugo cerviana Ser. Small herb widely scattered in gardens and cultivated situations.

x *Pharnaceum gracile* Fenzl. Slender herb. G. Potts, 478. (1907).

x *P.* sp. prob. *P. dichotomum* L. f. Grows in a pan west of Bloemfontein. Schultz, 829. (1915).

Hypertelis verrucosa (E. & Z.) Fenzl. Pioneer on heavy soils.

Galenia namaensis Schinz. Shrub 2 to 3 feet tall.

G. pubescens (E. & Z.) Druce (= *G. spathulata* Fenzl.). Pubescent prostrate perennial herb.

G. sp. Strong shrub 2 to 3 feet tall. Occurs on the banks of the Modder River. No. 64.

Tetragonia arbuscula Fenzl. Edible herb with bright yellow flowers. Occurs very sparingly in the Modder River valley in " brackish " sloots.

x *Bergeranthus glenensis* N.E. Br. (= *Mesembryanthemum scapigerum* Haw.). Yellow-flowered succulent growing on ironstone koppies near Bfn. Collector unknown, 1669.

Mestoklema tuberosum (L.) N.E. Br. (= *Mesembryanthemum tuberosum* L.). Succulent shrub.

Psilocaulon articulatum (Thunb.) N.E. Br. Much-branched perennial succulent with small white flowers. Occurs on waste spots and eroded situations on the banks of the Rhenosterspruit.

x *P. granulicaule* (Haw.) Schw. Recorded from Bfn. Stem and leaves greyish green, slightly foetid when crushed. D. M. Gemmell, 4896. (1934).

Ruschia caninotata (L. Bol.) Schw. Perennial succulent.

R. hamata (L. Bol.) Schw. (= *Mesembryanthemum hamatum* L. Bol.). Woody succulent, 1 to 2 feet high.

R. unidens (Haw.) Schw. Pioneer in the lithosere.

Aridaria tetragona (Thunb.) L. Bol. Inedible succulent forming thick clumps on disturbed soil in the Modder River valley. Uncommon.

x *Chasmatophyllum musculinum* (Haw.) Dinter and Schw. Occurs in grassy vleis and on koppies near Bfn. Low prostrate succulent rooting at the nodes. G. Potts, 1500, 1671. (1916).

Delosperma crassuloides L. Bol. Fairly abundant on slopes of a randjie, 10 miles east of Glen.

D. herbeum N.E. Br. Erect white-flowered succulent.

D. mahoni N.E. Br. Common pioneer.

x *D. pottsii* L. Bol. White-flowered succulent recorded from koppies north of Bfn. G. Potts, 3874. (1927).

D. sp. cf. *D. cooperi* (Hook f.) L. Bol. Perennial erect succulent, occurs occasionally in the Modder River valley. No. 257.

Drosanthemum asperulum (Harv.) Schw. Erect succulent shrublet. Sparsely scattered in overgrazed Vleiveld to the western part of this area. Pink-flowered.

Eberlanzia spinosa (L.) Schw. (= *Mesembryanthemum spinosum* L.). Robust bushy succulent.

x *Hymenocyclus* sp. Yellow-orange flowered succulent recorded from the Modder River valley at Glen. Rare.

Malephora mollis (Ait.) N.E. Br. Halophytic prostrate succulent occurring on dry bed of Saltpans. Pink-flowered.

Stomatium ermininum (Haw.) Schw. Small pioneer succulent.

S. mustellinum (S.D.) Schw. Typical cushion-like succulent.

x *Trichodiadema barbatum* (L.) Schw. Erect or scandent succulent occurring on dry parts of koppies in rock fissures. Fairly common. Probably eaten by rodents. V. C. Green, 5447. (1943).

T. pomeridianum L. Bol. Erect to scandent succulent.

Portulacaceae.

Talinum caffrum E. & Z. Widely but singly distributed on various soil types.

x *Anacampseros filamentosa* (Haw.) Sims. Leaves cob-webbed at the end. The cluster as a whole has a wooly appearance. Occurs on koppies. G. Potts, 1519. (1916).

A. rufescens (Haw.) Sweet. Chasmophyte with fleshy leaves and beautiful flowers.

A. telephiastrum D C. Characteristic pioneer in rocky situations.

A. ustulata E. Mey. Has silvery-grey cylindrical shoots 1 to 2 inches high.

Portulaca oleracea L. Weed of cultivation.

P. quadrifida L. Pioneer on stony and gravel soils.

Caryophyllaceae.

Stellaria media Cyrill. Common annual weed. Favours shady spots.

Sagina sp. Alien small tufted herb, 1 to 2 inches high. A few plants were found on a wet spot in Bfn. No. 646.

Spergula arvensis L. Annual erect weed. Rare.

Spergularia glandulosa Fenzl. var. *glabifolia* Fenzl. Diffused biennial yellow-flowered herb. Grows on the banks of the Modder River. Uncommon.

x *Polycarpon tetraphyllum* L. f. Weed growing on disturbed places at Bfn. W. J. Lütjeharms, 6048. (1941).

Pollichia campestris Ait. Perennial thick-rooted herb.

Herniaria hirsuta L. Perennial herb.

Silene burchellii Otth. Erect tufted herb.

S. capensis Otth. Occasional on wet cultivated places and in water-courses.

S. gallica L. Annual weed in gardens.

Dianthus micropetalus Ser. Herb.

D. scaber Thunb. Frequent on randjies.

Ranunculaceae.

Clematis brachiata Thunb. Common scandent vine.

x *Ranunculus aquatilis* L. More or less submerged hydrophyte. Rare. G. Potts, 1310. (1915).

R. drouetii Godr. & Schultz. Aquatic.

R. pubescens Thunb. (= *R. pinnatus* Poir.) Abundant in moist situations.

Thalictrum caffrum E. & Z. Perennial herb.

Menispermaceae.

x *Antizoma angustifolia* (Burch.) Miers *ex* Harv. [= *Antizoma calcarifera* (Burch.) Miers.]. Common scandent shrub growing underneath trees in the valleys. G. Potts, 1181. (1915).

A. harveyana Miers *ex* Harv. Scandent shrub.

Papaveraceae.

Argemone mexicana L. Common weed.

Papaver aculeatum Thunb. Winter weed in lands.

Fumariaceae.

Fumaria muralis Sond. Annual weed in gardens. Uncommon.

F. officinalis L. Scandent weed on irrigated lands at Glen and Bfn.

Cruciferae.

Heliophila suavissima Burch. Woody shrublet, 1 to 2 feet high.

Lepidium divaricatum (Poir.) Sol. Pioneer and weed in lands and disturbed situations. Common.

L. divaricatum Sol. sub. sp. *linoides* (Thunb.) Thell. Annual erect weed, rarely found on wet cultivated lands.

x *L. draba* L. Small whitish-flowered erect herb. Found at a roadside at Bfn. D. M. Gemmell, 6140. (1931).

L. pinnatum Thunb. Annual weed. Occurs rarely in gardens at Glen.

L. ruderale L. Erect herb.

L. schinzii Thell. Abundant, pioneer on bare heavy soils in the valleys.

L. trifurcum Sond. Tall species, 18 inches high.

Coronopus integrifolius Spreng. Small prostrate herb, found as a weed in gardens.

Sisymbrium sp. prob. *S. burchellii* D C. Perennial herb with a rootstock. Found under shade of trees near the Rhenosterspruit.

S. burchellii D C. var. *turczaninowii* (Sond.) Schultz. Perennial herb, 1 to 2 feet high. Weed in disturbed and wet sites.

S. capense Thunb. Erect herb.

S. capense Thunb. var. Widely scattered in moist situations in the Modder River valley. No. 385.

x *S. exasperatum* Sond. Weed in arboretum, Bfn. G. Potts, 783. (1915)

x *S. gariepinum* Burch. Herb recorded from the Rhenosterspruit. G. Potts, 802. (1915).

x *S. lyratum* Burm. Annual herb. Grows in shade of koppies near Bfn. G. Potts, 2617. (1917).

Brassica pachypoda Thell. Widely scattered in disturbed and waste places.

B. strigosa DC. Hygrophilous.

B. sp. Annual winter-weed in gardens. Uncommon. No. 519.

Raphanus raphanistrum L. Annual weed.

Nasturtium elongatum E. Mey. Hygrophilous herb.

N. officinale R. Br. Aquatic herb.

Rorippa caledonica (Sond.) R. A. Dyer (= *Nasturtium caledonicum* Sond..)

R. fluviatile (E. Mey. *ex* Sond.) R. A. Dyer (= *Nasturtium fluviatile* E. Mey *ex* Sond.). Perennial herb.

Capsella bursa-pastoris (L.) Medik. Annual winter weed.

Capparidaceae.

x *Cleome monophylla* L. Grows in gardens, Bfn. Very rare. V. C. Green, 5360. (1946).

Resedaceae.

Oligomeris dregeana Presl. Woody yellow-flowered herb. Scattered on hill slopes.

Crassulaceae.

Cotyledon decussata Sims. Succulent, widely scattered on randjies.

Adromischus trigynus (Burch.) v. Poelln. (= *Cotyledon trigyna* Burch.). Leaves have numerous small purple spots.

Kalanchoe paniculata Harv. Fleshy herb, 2 to 3 feet tall.

x *K. rotundifolia* Haw. (= *K. pottsii* Schonl.). Recorded from Bfn. G. Potts, 3716. (1927).

x *Crassula cooperi* Regel. Grows amongst rocks on the side of sloots near Bfn. G. Potts, 2197. (1917).

x *C. corallina* Thunb. (= *C. dasyphylla* Harv.). Pioneer occurring between rocks on hills. G. Potts, 2196. (1917).

x *C. fruticulosa* L. (prob.). White-flowered herb. Occurs amongst boulders on hills. G. Potts, 2198. (1917).

C. muscosa L. [= *C. campestris* (E. & Z.) Harv.]. Low delicate herb.

C. sp. cf. *C. muscosa* L. Small short-lived delicate herb. Occasionally found as a pioneer on bare spots in the valley of the Modder River, Glen. No. 878.

C. natans Thunb. Aquatic herb.

x *C. nodulosa* Schon. Erect succulent herb. Recorded from Bfn. G. Potts, 392. (1907).

C. platyphylla Harv. Perennial herb.

x *C. transvaalensis* (O. Ktze.) K. Schum. [= *C. subulata* (Hook) Harv.]. Small herb approximately two inches high. Grows in short open grassveld on sandy soils. G. Potts, 3470. (1925).

C. schmidtii Reg. Annual herb. Grows in shade of boulders on randjies.

C. sp. cf. *C. turrita* Thunb. Erect herb. No. 212.

C. sp. Succulent herb preferring cool situations on randjies. Rare. No. 215.

Saxifragaceae.

Vahlia capensis Thunb. Perennial herb.

Rosaceae.

Potentilla supina L. Perennial herb.

Alchemilla elongata E. & Z. Perennial decumbent herb.

x *Leucosidea sericea* E. & Z. Shrub occurring on a koppie near water at Mazelspoort. M. Swift, 5100. (1937).

Leguminosae.

Acacia karroo Hayne. Common tree.

A. stolonifera Burch. Bushy shrub. Singly scattered in western part of this area. Uncommon.

Elephantorrhiza elephantina (Burch.) S. Keels (= *E. burchellii* Benth.). Shrublet.

Cassia mimosoides L. Small prostrate yellow-flowered herb.

C. obovata Collad. Prostrate shrub.

Lotononis burchellii Benth. Prostrate perennial confined to lands, especially sandy soils.

x *L. calycina* Benth. (= *L. tenella* E. & Z. var. *calycina* Harv.). Prostrate herb growing in grassveld. Uncommon. G. Potts, 1328. (1915).

L. divaricata Benth. Blue-flowered shrublet. Scattered on banks of the Rhenosterspruit.

L. laxa E. & Z. Woody slender-stemmed herb.

L. leobordea Benth. Forms dense mats approximately 3 to 6 inches in diameter.

x *L. tenella* E. & Z. var. Prostrate tufted herb. Grows on bare soils. G. Potts, 2940. (1917).

x *L. woodii* Bol. Minute prostrate herb growing on bare soils. G. Potts, 1996. (1915).

L. sp. cf. *L. bainesii* Bak. Perennial herb.

x *L.* sp. cf. *L. lenticula* Benth. Prostrate pioneer on hard bare soil surfaces. G. Potts, 2911. (1917).

Listia heterophylla E. Mey. Common perennial legume.

Dichilus gracilis E. & Z. Yellow-flowered herb, recorded from koppies.

x *D. lebbechioides* DC. Shrubby, 1 to 2 feet high. Recorded from Bfn. D. M. Gemmell, 4947A. (1934).

Melolobium calycinum Benth. Thorny shrub, about one foot high.

x *M. candicans* E. & Z. Thorny shrub. G. Potts, 2032. (1915).

x *M. cernuum* E. & Z. Perennial herb about one foot high. Grows amongst grasses in veld. G. Potts, 1531. (1916).

x *M. decumbens* (E. Mey) Benth. [= *M. microphyllum* (Thunb.) E. & Z. var. *decumbens* (E. Mey) Harv.]. Yellow-flowered shrublet. Grows on red sandy soils. G. Potts, 24. (1905).

x *M.* sp. prob. *M. obcordatum* Harv. Recorded from Bfn. G. Potts, 2921. (1917).

Crotalaria distans Benth. Annual.

C. podocarpa DC. Probably an annual. Yellow flowered. Recorded from Bfn.

Argyrolobium nanum Schltr. (prob.) Edible herb.

A. pauciflorum E. & Z. Perennial undershrub.

x *A. rupestre* Walp. Erect herb found in Bfn. D. Snoek, 4916. (1936).

A. sp. Small undershrub. Uncommon, grows on slopes of koppies. No. 437.

Trigonella hamosa L. Prostrate herb.

Medicago denticulata Willd. Prostrate herb.

M. laciniata All. Annual prostrate herb.

x *M. nigra* Willd. Prostrate perennial herb. G. Potts, 476. (1907).

Melilotus albus Desr. Biennial erect legume.

M. indicus All. (= *M. parviflora* Desf.). Annual erect herb.

Trifolium africanum Ser. Creeping clover.

T. dubium Sibth. Prostrate clover.

Indigofera alternans DC. Deep rooted herb.

I. argyraea E. & Z. Prostrate perennial.

I. cryptantha Benth. Shrub.

I. filipes Benth. Erect herb with reddish flowers. Grows between grasses on red sandy soils.

I. holubii N.E. Br. Prostrate pioneer.

I. patens E. & Z. Shrub.

I. rhytidocarpa Benth. Prostrate annual pioneer growing on the eroded banks of the Modder River.

I. spinescens E. Mey. Erect shrub. Scattered on heavy soils on level plains.

x *I. zeyheri* Spreng. Bush, two feet high and three feet across. Grows on koppies. G. Potts, 2907. (No date).

Psoralea obtusifolia DC. Common prostrate legume.

Tephrosia capensis (Jacq.) Pers var. Perennial herb.

T. lurida Sond. Large showy bright pink-flowered legume. Occurs on slopes of koppies. Rare.

T. macropoda (E. Mey) Harv. Recorded from Bfn. Rare.

T. polystachya E. Mey var. Uncommon.

Sesbania mossambicensis Klotzsch. Robust annual, 2 to 4 feet tall.

x *Sutherlandia humilis* Phill. & Dyer. Collected by A. Lyle at Hillandale, Bfn. 1106. (1926).

S. microphylla Burch. *ex* DC. Erect perennial. Strong acrid smell when picked.

x *Lessertia annularis* Burch. Erect herb, grows on rich soils at the foot of hills. V. C. Green, 5476. (1943).

L. pauciflora Harv. Prostrate perennial.

x *L. prostrata* DC. Perennial prostrate herb. Pioneer on hard bare soil. G. Potts, 2944. (1917).

x *L. tenuifolia* E. Mey. Bluish-purple-flowered herb. Recorded from Naval Hill, Bfn. G. Potts, 2968. (1924).

x *L.* sp. prob. *L. depressa* Harv. Undershrub. Found in Bfn. G. Potts, 466. (1907).

x *L.* sp. prob. *L. physodes* E. & Z. Perennial herb. Recorded from Bfn. G. Potts, 3. (1905).

Vicia hirsuta (L.) Gray. Annual winter vetch. Weed in gardens.

V. sativa L. Volunteer annual which escaped from cultivation. Common on irrigated lands.

V. sativa L. x *V. villosa* Roth. Annual on cultivated irrigated lands.

Erythrina zeyheri Harv. Grows in dense patches in a spruit near Bfn. Uncommon.

Rhynchosia confusa Burtt Davy. Trailing undershrub.

R. memnonia DC. Prostrate herb.

R. totta DC. Perennial herb.

x *R. viscidula* Steud. var. Trailing legume, recorded from Bfn. G. Potts, 98. (1906).

x *Dolichos angustifolius* E. & Z. Annual twining herb growing in lands and in Themeda-grassveld. G. Potts, 1993. (1915).

x *D. linearis* E. Mey. Perennial trailing herb, 1 to 2 feet high. Grows on sides of koppies. G. Potts, 3318. (1924).

x *D. gibbosus* Thunb. Perennial herb with twining stems. Grows in shade of trees in kloofs. G. Potts, 1497. (1916).

Geraniaceae.

x *Geranium caffrum* E. & Z. var. Herb, 3 to 4 feet high. Grows in shade of trees on spruit-banks. G. Potts, 2821. (1917).

Monsonia biflora DC. Pioneer.

M. burkeana Planch. Erect herb occurring on damp sandy soils.

Pelargonium aridum R. A. Dyer (= *Pelargonium dissectum* E. & Z.). Perennial herb, showy yellowish flowered.

P. fumarioides L'. Her. Prostrate pioneer on waste places.

x *P. myrrhifolium* Ait. Herb, recorded from a koppie near Bfn. N. Lincoln, 5692. (1950).

x *P. reniforme* Curt. Perennial aromatic herb occurring on koppies. G. Potts, 2818. (1917).

Oxalidaceae.

x *Oxalis convexula* Jacq. Recorded from Bfn. G. Potts, 162. (No date).

O. corniculata L. Frequently found on shady spots on hill slopes.

O. depressa E. & Z. Scattered on moist situations.

O. latifolia H.B.K. Occurs in shade.

Linaceae.

Linum thunbergii E. & Z. Yellow-flowered erect herb occurring in shade of trees on hill slopes.

Zygophyllaceae.

Zygophyllum simplex L. Prostrate herb. Common as a halophyte on dry beds of Saltpans.

Tribulus terrestris L. Commonly found as a pioneer.

Polygalaceae.

x *Polygala abyssinica* Fresen. Perennial herb growing on red sandy soils amongst grasses. G. Potts, 2839. (1917).

P. hottentotta Presl. Deep-rooted undershrub. Occurs on eroded banks of the Modder River.

Euphorbiaceae.

Phyllanthus humilis Pax. Perennial herb. Grows at foot of hills amongst grasses.

P. maderaspatensis L. Common perennial pioneer.

Acalypha segetalis Müll. Arg. Annual pioneer.

x *Clutia pulchella* L. Recorded from Signal Hill, Bfn. G. Potts, 2088. (1909).

C. pulchella L. var. *obtusata* Sond. Shrub, 2 to 4 feet tall.

x *Euphorbia* sp. cf. *E. aspericaulis* Pax. Grows between boulders on koppies near Bfn. G. Potts, 1228. (1916).

Euphorbia clavarioides Boiss. Stem succulent.

E. catervaeflora N.E. Br. Erect succulent.

E. helioscopia L. Weed on disturbed sites. Uncommon.

E. inaequilatera Sond. Common pioneer on disturbed sites.

x *E. inaequilatera* Sond. var. *perennis* N.E. Br. Prostrate herb rooting at the nodes. Occurs on gravel soils. G. Potts, 2927. (1917).

E. mauritanica L. Common succulent.

x *E. preslii* Guss. Weed occurring in gardens. G. Potts, 2778. (1922).

E. prostrata Ait. Common annual pioneer.

E. rectirama N.E. Br. Succulent shrub.

x *E. serpens*. H.B.K. Prostrate pioneer. An introduced acclimatised weed. G. Potts, 2928, 2929. (1917).

E. striata Thunb. Erect herb.

x *E.* sp. cf. *E. rudolfi* N.E. Br. Grows at the foot of a koppie near Bfn. Three feet high. G. Potts, 822. (1915).

Anacardiaceae.

Rhus ciliata Licht. Common shrub.

R. erosa Thunb. Common shrub scattered on hill slopes.

R. lancea L. f. Evergreen tree.

R. pyroides Burch. Frequent tree.

x *R. undulata* Jacq. Grows on koppies at Bfn. G. Potts, 3857, 3498. (1924).

R. undulata Jacq. var. *burchellii* (Sond.) Schonl. (= *R. burchellii* Sond.). Common on randjies.

Celastraceae.

x *Gymnosporia polyacantha* Szysz. White-flowered shrub with an unpleasant smell. Grows on koppies. G. Potts, 55. (1906).

G. saxatilis (Burch.) Davison (= *Celastrus saxatilis* Burch.). Thorny shrub.

G. sp. nr. *G. saxatilis* Davison. Shrub, less frequently found on stony hill slopes. No. 69.

Rhamnaceae.

Ziziphus mucronata Willd. Widely scattered tree.

Vitaceae.

Cissus hereroensis Schinz. Perennial erect herb.

Tiliaceae.

Corchorus asplenifolius Burch. Perennial herb.

x *C.* sp. nr. *C. asplenifolius* Burch. Prostrate herb. Recorded from Bfn. G. Potts, 2112. (1907).

Grewia flava DC. Tree, six feet tall. Occurs on the slopes of hills and ridges to the western part of the area.

G. occidentalis L. Shrub.

Malvaceae.

x *Abutilon sonneratianum* Sweet. Very plentiful under trees in kloofs. Erect shrub. G. Potts, 20. (1905).

Sphaeralcea bonariensis (Cav.) Grieseb. (= *Sida cordifolia* L.). Perennial undershrub with numerous flesh-coloured flowers. Scattered singly in spruits.

Malva parviflora L. Winter-growing pioneer favouring moist situations.

Sida dregei Burtt Davy (= *S. longipes* E. Mey). Perennial shrublet.

Pavonia burchellii (DC.) R. A. Dyer (= *P. macrophylla* E. Mey). Perennial herb confined to shady places under trees, Glen.

x *Callirhoe* sp. prob. *C. involucrata* Gray. Prostrate herb recorded from Victora Park, Bfn. D. M. Gemmell, 5159. (1940).

x *Hibiscus aethiopicus* L. Herbaceous perennial about six inches high. Occurs between grasses at foot of hills. G. Potts, 2840. (1917).

H. atromarginatus E. & Z. Perrenial shrublet.

H. malacospermus E. Mey. Perennial shrublet.

H. marlothianus K. Sch. Perennial shrublet.

H. pusillus Thunb. Perennial shrublet.

H. trionum L. Annual herb.

Sterculiaceae.

Hermannia bryoniaefolia Burch. Perennial undershrub.

H. coccocarpa (E. & Z.) O. Ktze. (= *Mahernia coccocarpa* E. & Z.). Erect perennial herb.

H. comosa Burch. Perennial herb growing in lands.

H. depressa N.E. Br. Prostrate herb.

H. erodioides Burch. Herb, 1 to 3 inches high.

H. leucophylla Presl. Perennial erect herb. Sparsely spread on lands and disturbed situations.

H. linearifolia Harv. Shrub, approximately one foot high.

H. linnaeoides (Burch.) K. Schum. Prostrate herb.

x *H. pallens* E. & Z. Shrub, 2 to 3 feet high. Fairly common on koppies. G. Potts, 6. (1906).

H. tomentosa Schinz. (= *H. brachypetala* Harv.). Prostrate perennial herb with long creeping stems covering an area about five feet across. Grows on red sandy soils.

Cactaceae.

x *Opuntia lasiacantha* Pfeiffer. Acclimatised succulent. Collected by a native Jacob, 3993. (1929).

x *O. maxima* Mill. Acclimatised succulent. Widely scattered on randjies in this area. G. Potts, 3991. (1929).

O. megacantha Salm Dyck. Scattered on hills. Acclimatised.

O. imbricata (Haw.) DC. Forms isolated dense clumps at roadsides near Bloemspruit.

Thymelaeaceae.

Lasiosiphon capitatus (L. f.) Burtt Davy. Small shrublet, 1 to 2 feet tall. Occurs on stony slopes of rises.

Arthrosolen polycephalus C. A. Mey (= *Lasiosiphon polycephalus* Pears). Perennial shrub with rodlike branches and yellow flowers. Occurs on trampled-out bultveld.

Lythraceae.

x *Lythrum hyssopifolium* L. Herb, recorded from flushes near Bfn. G. Potts, 3521. (1925). Uncommon.

Onagraceae.

Oenothera biennis L. Robust biennial herb, 1 to 2 feet high.

O. indecora Camb. Perennial erect herb found on roadsides.

O nocturna Jacq. Erect herb.

O odorata L. Erect perennial herb.

O. rosea Ait. Erect herb.

O. tetraptera Cav. Perennial herb.

O. sp. nov. (= de Jongh & Galpin No. 6529, Barnard No. 578, Burtt Davy No. 1248). Erect herb, 2 to 4 feet tall. Scattered on the steep banks of the Modder River. Uncommon. No. 96.

Araliaceae.

Cussonia paniculata E. & Z. Thick-rooted tree.

Umbelliferae.

x *Heteromorpha arborescens* Cham. & Schl. Shrub up to eight feet tall. Occurs in flushes north of Bfn. Uncommon. G. Potts, 1413, 1499. (1916).

Bupleurum mundtii Cham. & Schl. Yellow-flowered herb.

x *Apium graveolens* L. Occurs in spruits on sheltered moist situations· Perennial rootstock. Smells like celery. G. Potts, 1309. (1915).

A. leptophyllum (Pers.) F. Muell. Erect herb.

Pituranthos burchellii (DC.) Schinz. Rigid almost leafless perennial shrublet.

Pimpinella caffra (E. & Z.) Harv. Grows in wet situations.

Berula thunbergii (DC.) Wollf. (= *Sium thunbergii* DC.). Erect semi-aquatic herb.

Anesorrhiza (prob.) *macrocarpa* E. & Z. Erect herb, probably biennial.

Choritaenia capensis (Sond. & Harv.) Benth. Annual prostrate herb.

Daucus carota L. Erect herb, 2 to 3 feet tall. Found in vleis.

x *Seseli chaerophylloides* Thunb. Erect herb, four feet tall. Occurs on edges of cultivated ground and in wet spruits.

Primulaceae.

x *Anagallis arvensis* L. Annual weed in lands. G. Potts, 3605. (1917).

x *A. arvensis* var. *coerulea* Gren. and Godr. Weed of cultivation and occurs on moist places. Collected by a native Jacob, 4563. (1930).

Ebenaceae.

x *Royena hirsuta* L. Low broad shrub, four feet tall, 5 to 6 feet broad. G. Potts, 2024. (1916).

R. hirsuta L. var. Erect shrub up to eight feet high. No. 546.

R. hirsuta L. var. *microphylla* (Burch.) de Winter MS. (= *R. pallens* Thunb.). Evergreen shrub. Rare. Grows along beds of spruits near Bfn.

R. lycioides (Desf.) DC. Shrub.

Euclea lanceolata E. Mey. Frequent in ravines and on randjies.

E. ovata Burch. Evergreen shrub.

Oleaceae.

Olea africana Mill. (= *O. verrucosa* Link.). Evergreen tree.

Menodora africana Hook. Shrublet.

Loganiaceae.

Gomphostigma virgata (L. f.) Baill. (= *G. scoparioides* Turcz.). Hygrophilous shrub.

Buddleja salicifolia Jacq. (= *Chilianthus arborens* A. DC.). Common tree on koppies.

Gentianaceae.

Sebaea compacta A. W. Hill. Small herb.

S. conrathii Schinz. Small herb, 1 to 3 inches high. Rarely found on sandbanks in the Modder River.

x *S. exigua* Schinz. Collected on University grounds, Bfn. Very rare. D. M. Gemmell, 6623. (1953).

S. pentandra E. Mey. Erect annual herb.

S. sp. cf. *S. pentandra* E. Mey. Annual erect herb. A few plants were found in the Modder River. No. 617.

x *Exochaenium* sp. (prob.). Herb, two inches high. Occurs in grassveld. Uncommon. G. Potts, 2424. (1917).

Apocynaceae.

Pachypodium succulentum A. DC. Succulent shrub with a large tuberous root system. Occurs on koppies. Rare.

Asclepiadaceae.

Raphionacme hirsuta (E. Mey) R. A. Dyer (= *R. divaricata* Harv.). Perennial herb.

R. zeyheri Harv. Perennial herb.

Xysmalobium undulatum (L.) Ait. f. Scattered in flushes.

Schizoglossum eustegioides (E. Mey) Druce (= *S. crassipes* Moore). Perennial thick-rooted herb.

x *S. aciculare* N.E. Br. Grows on top of Naval Hill, Bfn. D. M. Gemmell, 3939. (1929).

x *Cordylogyne globosa* E. Mey. Grows on damp ground in vleis and near dams. Rare. G. Potts, 1244. (1915).

x *Pachycarpus dealbatus* (Decne.) E. Mey. Erect herb, 1 to 2 feet high, occurs in vleis and depressions. G. Potts, 245. (1907).

Asclepias burchellii Schltr. Perennial woody herb.

x *A. crispa* Berg. Herb, recorded from Tempe, Bfn. D. M. Gemmell, 3558. (1925).

A. fruticosa L. Strong erect weed.

A. gibba Schltr. Herb occurring in Themeda grassveld north-west of Bloemfontein.

A. meyeriana Schltr. Small thick-rooted herb.

x *A. multicaulis* Schltr. Thick-rooted herb growing in grassveld. D. M. Gemmell, 5981. (1938).

x *A. stellifera* Schltr. Occurs on rocky sides of koppies near Bfn. D. M. Gemmell, 4940. (1925).

Cynanchum virens Dietr. Leafy twining herb.

Sarcostemma viminale (L.) R. Br. Leafless creeping succulent.

Brachystelma foetidum Schltr. Perennial herb.

B. galpinii (Schltr.) N.E. Br. Small herb with tuberous rootstock. Recorded from Bfn.

B. sp. Yellowish-flowered herb with a thick tap root. Rarely found on bults, Glen. No. 219.

Riocreuxia polyantha Schltr. Twiner, 4 to 5 feet high.

x *Duvalia corderoyi* N.E. Br. Small succulent, 1 to 2 inches high. G. Potts, 2586, 2573. (1924).

Caralluma lutea N.E. Br. Common succulent.

Stapelia flavirostris N.E. Br. Common succulent.

x *S. gemmiflora* Mass. Succulent, grows on koppies. G. Potts, 2587. (1917).

x *Tenaris* sp. (prob.). Very delicate plant recorded from ironstone koppies. G. Potts, 2189. (1915).

Convolvulaceae.

Cuscuta campestris Yunck. Stem parasite.

Falkia oblonga Bernh. Thick-matted herb.

Seddera capensis (E. Mey *ex* Choisy) Hall f. (= *Breweria capensis* Bak.). Common herb.

Convolvulus arvensis L. Common rhizomatous weed.

C. boedeckerianus Peter. Perennial herb.

C. dregeanus Choisy (= *C. liniformis* Rendle). Twining deep-rooted herb.

C. sagittatus Thunb. (= *C. phyllosephalus* Hall f.). Twining herb from a woody tap root.

C. sagittatus Thunb. var. *latifolius* C. H. Wr. Stoloniferous herb.

C. ulosepalus Hall f. The most common form with long twining-trailing stems. Widely scattered.

C. ulosepalus Hall f. (= Acocks & Häfström Nos. A. 11332, H. 1160). Leafy form fairly frequently found in the valleys and edges of lands.

C. ulosepalus Hall f. (= Moraile No. 5001, Liebenberg No. 3195, named *C.* sp. nr. *C. ulosepalus* Hall f.). Broad-leaved. Scattered singly on heavy soils and in irrigated lands.

x *C.* sp. cf. *C. capensis* Burm. f. var. Small erect herb growing in " brackish " soils. G. Potts, 1316. (1915).

Ipomoea bolusiana Schinz. Large bright-pink flowered. Occurs in Valley grassveld.

I. crassipes Hook. Prostrate twining herb with large leaves.

I. oblongata E. Mey *ex* Choisy. Twining herb.

I. obscura (L.) Ker. Gawl. Twining herb.

I. oenotheroides (L. f.) Raf. (= *I. argyrioides* Choisy). Erect shrublet.

I. simplex Thunb. Small erect herb, rather rare.

Merremia verecunda Rendle (= *I. quinquefolia* Hochst.). Prostrate herb.

Boraginaceae.

Ehretia rigida (Thunb.) Druce. Shrub.

Tournefortia tuberculosa Cham. Perennial thick-rooted herb.

Heliotropium currassavicum L. Perennial erect herb, pioneer on sand-banks in the Modder River.

H. lineare (E. Mey *ex* Drege.) C.H. Wr. Perennial erect herb. Roadside pioneer.

H. zeylanicum Lam. Erect herb, creamish-flowered. Roadside pioneer.

Trichodesma angustifolium Harv. Erect herb. Occurs very rarely on stony outcrops near Brandfort.

Lappula echinata Gilib. (= *Echinospermum lappula* Lehm.). Erect herb, found on lands and disturbed sandy situations.

Amsinckia angustifolia Lehm. Annual weed in lands, Glen. Rare.

Anchusa capensis Thunb. (= *A. riparia* DC.). Robust perennial herb.

Lithospermum cinereum DC. Undershrub, 1 to 2 feet high. Found in lands.

L. hirsutum E. Mey *ex* DC. Perennial herb. Grows in shade of trees on banks of watercourses.

Verbenaceae.

Verbena bonariensis L. Strong erect herb, 2 to 3 feet tall.

V. officinalis L. Common on wet situations.

V. tenera Spreng. A garden escape.

x *V.* sp. Prostrate herb recorded from Bfn. G. Potts, 2079. (1907).

Lantana salviaefolia Jacq. Low mauve-flowered undershrub.

Lippia canescens Kunth. Matted herb.

x *L. reptans* H.B. & K. Matted herb. D.M. Gemmell, 3523. (1925).

Chascanum pinnatifidum (L. f.) E. Mey. Low shrublet.

Clerodendrum triphyllum (Harv.) H. H. W. Pearson. Found in Themeda grassveld. Rare. Blue-flowered. Collected by J. Morris.

Labiatae.

Teucrium capense Thunb. Perennial undershrub.

Acrotome inflata Benth. Erect herb. Grows in lands and on disturbed sites.

Leucas martinicensis R. Br. Undershrub. Rare, grows on the banks of watercourses.

Stachys hyssopoides Benth. Herb.

x *S. spathulata* Burch. Perennial aromatic herb with rhizomes. Occurs on red sandy soils. G. Potts, 2825. (1917).

Salvia clandestina L. var. *angustifolia* Benth. Widely distributed pioneer.

S. farinacea Benth. Showy blue-flowered erect herb. Grows near water on lower banks of the Modder River. Escaped cultivation.

S. rugosa Dryand *ex* Ait. Robust pioneer.

S. runcinata L. f. Singly scattered on bare soils.

S. stenophylla Burch. Perennial herb, 12 inches high. Grows amongst grasses in vleis and on flats.

Becium obovatum N.E. Br. Rare herb, occurs in Themeda grassveld.

Lamium amplexicaule L. Introduced weed. Grows in gardens.

Solanaceae.

Lycium echinatum Dunal. Shrub, 4 to 8 feet tall.

L. hirsutum Dunal. Shrub, up to 10 feet tall.

L. kraussii Dunal. Shrub, about one foot tall. Spread by undergrowth runners. Recorded from bults and koppies at Bfn. and Glen. Fairly frequent.

x *L.* sp. prob. *L. acutifolium* E. Mey. Shrub, six feet tall. Recorded from Bfn. G. Potts, 2856. (1917).

L. sp. cf. *L. oxycladum* Miers. Shrub, 2 to 3 feet tall. No. 267.

x *L.* sp. prob. *L. tenue* Willd. Shrublet recorded from Bfn. G. Potts, 2844. (1917).

Withania somnifera Dunal. Prostrate shrub, scattered on old meerkat burrow on bults.

x *Physalis angulata* L. Annual weed in lands.

x *P. viscosa* L. Collected at the side of a path at the University. D. M. Gemmell, 6626. (1953).

Solanum coccineum Jacq. Spiny shrub, 1 to 2 feet high. Sparsely scattered on hill slopes.

S. incanum L. Big-leaved shrub, frequently found on distrubed places.

S. leucophaeum Dunal. Spiny herb. Scattered at roadsides and disturbed sites especially towards the western part of this area.

S. nigrum L. Annual herb, found on cultivated lands.

S. panduraeforme E. Mey. Perennial shrublet.

S.. rostratum Dunal. Spiny undershrub with large showy yellow flowers.

S. supinum Dunal. Small white-flowered shrub occurring on overgrazed places.

x *S. tomentosum* L. Shrub growing on hills. G. Potts, 3323.

S. sp. nov. nr. *S. tomentosum* L. Spiny undershrub. Only a few plants were found. No. 125.

S. sp. prob. *S. sodomeum* Drége. Thick-rooted undershrub rarely encountered on lands. No. 823.

Datura ferox L. Annual weed in lands.

D. stramonium L. Annual weed of cultivation.

Cestrum parqui L'. Her. Stoloniferous shrub.

Nicotiana glauca R. Grah. Sub-arborescent woody perennial.

Scrophulariaceae.

Aptosimum depressum Burch. Prostrate perennial.

A. depressum Burch. var. *elongatum* (Engl.) Hiem. (= *A. elongatum* Engl.). Wiry prostrate perennial.

x *A. leucorrhizum* (E. Mey) Phillips (= *Peliostomum leucorrhizum* E. Mey). Low undershrub, abount six inches high. Occurs amongst grasses on hills and rises. G. Potts, 2034. (1915).

A. origanoides (E. Mey) Phillips (= *Peliostomum origanoides* E. Mey). Shrublet.

Nemesia affinis Benth. Annual herb.

x *N. floribunda* Lehm. Occurs in patches near roadsides, Glen. Rose-coloured flowers. D. M. Gemmell, 5689. (1950).

x *N. foetens* Vent. Widely scattered. Favours shade of trees. Pink-flowered. D. M. Gemmell, 3866. (1925).

N. hanoverica Hiern. Annual herb.

x *N. picta* Schl. Small herb, recorded from Bfn. Miss Bidwell, 2965. (No date).

x *N. pubescens* Benth. Perennial herb, 8 to 10 inches high. Recorded from koppies near Bfn. G. Potts, 1136. (1915).

x *Diclis petiolaris* Benth. Delicate herb growing amongst grasses in wet ground near pools. G. Potts, 2383. (1917).

x *Manulea benthamiana* Hiern. Annual herb occurring on periodic flooded situations, 5 to 6 inches tall. G. Potts, 3513. (1922).

x *M. crassifolia* Benth. Showy russet-brown flowered species growing on deep bare sandy soils. G. Potts, 1318. (1915).

x *M.* sp. cf. *M. androsacea* E. Mey. Annual herb growing on bare ground. Flowers white with yellow centre. G. Potts, 2378. (1917).

Sutera albiflora Verdoorn. Woody shrublet.

S. argentea Hiern. Shrublet, recorded from koppies at Bfn.

S. atropurpurea Hiern. Shrublet.

S. aurantiaca Hiern. Small orange-flowered shrublet. Scattered between grasses on hill slopes.

S. caerulea (L. f.) Hiern. Aromatic shrublet encountered on hill slopes, etc.

x *S. crassicaulis* (Benth.) Hiern. Undershrub, about one foot high. Grows on foot of koppies. G. Potts, 2045. (1915).

S. halimifolia (Benth.) O. Kuntze. Erect herb, scattered in Themeda grassveld and on randjies. Rare.

x *S. neglecta* (Wood and Evans) Hiern. Erect herb. Recorded from Bfn. G. Potts, 2071. (1907).

S. pristisepala Hiern. Deep rooted undershrub.

x *S.* sp. nr. *S. canescens* Hiern. Shrub, two feet tall. Grows on hills. Uncommon. G. Potts, 3289. (1917).

x *Zaluzianskya crocea* Schltr. Small ephemeral herb occurring in short open grassveld on sandy soils. G. Potts, 3514. (1922).

x *Z. gilioides* Schltr. Erect herb, collected at Shannon, Bfn. J. Hatchard, 5259. (1925).

Mimulus gracilis R. Br. Hygrophilous yellow-flowered herb.

Limosella longiflora O. Kuntze. (= *L. tenuifolia* Mett., *L. aquatica* L. var. *tenuifolia* Hook f.). Small herb about one inch high.

L. capensis Thunb. Aquatic herb.

x *L. grandiflora* Benth. Small herb occurring on marshy soils. G. Potts. 1322. (1915).

Hebenstreitia dentata L. Weed of cultivation. Fairly frequent.

Selago albida Choisy. Undershrub. Occurs in the valleys.

S. speciosa Rolfe. Shrublet.

Walafrida basutica Phillips. Shrub, 1 to 2 feet tall. Grows on disturbed places in Themeda-veld. Rare.

x *W. decipiens* Rolfe. Undershrub, one foot high. Occurs on sandy soils and has an unpleasant smell. G. Potts, 1135. (1915).

W. densiflora Rolfe. Shrublet. Common at roadsides.

W. geniculata Rolfe. Blue-flowered shrublet.

W. paniculata Rolfe. Shrublet.

W. saxatalis Rolfe. Shrublet. Common on roadsides and disturbed areas.

Veronica anagallis L. Aquatic.

x *V. polita* Fr. Annual introduced weed. G. Potts, 3509. (1917).

x *V. persica* Desf. (= *V. tournefortia* K. C. Gmel.). Bright blue-flowered weed occurring on irrigated gardens and lands, Bfn. D. M. Gemmell, 5691. (1950).

Alectra orobanchoides Benth. (= *Melasma orobanchoides* Engl.). Rare.

x *Striga gesnerioides* (Willd.) Vatke. Parasitic apparently on Themeda in veld near Bfn. D. M. Gemmell, 5108. (1938).

S. bilabiata (Thunb.) O. Kuntze (= *S. thunbergii* Benth.). Perennial parasitic herb.

x *Harveya pumila* Schltr. Root parasite occurring on the banks of the Rhenosterspruit. Rare. G. Potts, 3320. (1917).

x *H.* sp. prob. *H. purpurea* Harv. Grows in veld on banks of a spruit near Bfn. Total root parasite. G. Potts, 1948. (1915).

Bignoniaceae.

Rhigozum obovatum Burch. Shrub.

Pedaliaceae.

Pterodiscus speciosus Hook. Perennial herb with a large tuber and showy pink-purple flowers. Very rare.

Harpagophytum procumbens (Burch.) DC. Trailing herb.

Sesamum capense Burm. f. Annual erect herb. Occurs in lands and disturbed situations.

Martyniaceae.

x *Proboscidea lutea* Stapf. (= *Martynia montevidensis* Cham.). Rare in veld near Bfn; yellow-flowered. Collector unknown, 1918. (No date).

Acanthaceae.

Thunbergia dregeana Nees. Perennial rambler.

x *Grabbea circioides* Nees. Rare, grows on hills. G. Potts, 2576. (1917).

C. nana Nees. Decumbent shrublet. Sparsely scattered in open Themeda grassveld.

Barleria macrostegia Nees. Prostrate suffrutice.

Blepharis integrifolia (L. f.) E. Mey (= *B. molluginifolia* Pers.). Procumbent herb.

Plantaginaceae.

Plantago dregeana Presl. Weed in gardens and on moist situations.

P. lanceolata L. Abundant on wet situations.

P. major L. Common in watercourses.

Rubiaceae.

Kohautia cynanchica DC. [= *Oldenlandia cynanchica* (DC.) K. Schum. *ex* O. Kuntze; and *Hedyotis stricta* Sond.]. Perennial herb scattered on roadsides.

Pentanisia sp. Perennial herb. Occurs in Themeda grassveld. Rare. No. 825.

Pachystigma sp. Dwarf plant growing on stony hills. Very rare. No. 824.

Anthospermum rigidum E. & Z. Woody shrublet. Common in overgrazed valleys and occurs often as a tree undergrowth.

Nenax microphylla (Sond.) Salter. Evergreen shrub.

x *Rubia* sp. Grows under trees and shrubs at Floradale, Bfn. G. Potts, 2747. (1922).

x *Galium capense* Thunb. Herb, grows in vleis. Collected by a native, John, 5002. (1953).

G. garipense Sond. Scabrous-stemmed herb.

G. horridum Thunb. Rambling herb.

Dipsacaceae.

Scabiosa columbaria L. Perennial herb.

Cucurbitaceae.

Pisosperma capense Sond. Small trailing herb arising from a large tuber.

Kedrostis africana (L.) Cogn. Occasionally found in valleys.

x *K.* (= *Coniandra*) *digitata* (Thunb.) Cogn. Recorded from the town commonage, Bfn. G. Potts, 2789. (1918).

K. punctulata (Sond.) Cong. Scandent herb.

Citrullus vulgaris Schrad. Annual prostrate herb. Grows on lands and distrubed places in veld.

Cucumis africanus L. Procumbent vine, occasionally found in Themeda grassveld.

C. heptadactylus Naud. Precumbent vine. Occasional in Themeda grassveld.

C. myriocarpus Naud. Procumbent vine. Occasional on maize lands.

Peponium caledonicum (Sond.) Engl. Prostrate herb. Grows in rock crevices on krantzes near Glen. Rare.

Coccinea sessilifolia (Sond.) Cogn. Prostrate to twining herb, frequent on banks of watercourses.

Campanulaceae.

Wahlenbergia androsacea A. DC. Annual herb.

W. arenaria A. DC. (= *W. nudicaulis* E. & Z.). Erect herb favouring wet situations.

W. banksiana A. DC. Erect creamish-flowered herb. Rather rare.

W. caledonica Sond. Erect herb, 1 to 2 feet high. Occurs amongst grasses on wet situations.

W. procumbens A. DC. Prostrate perennial herb.

W. undulata (Thunb.) A. DC. Herb, occasional on wet situations.

Lightfootia albens Spreng. Small undershrub.

L. denticulata Sond. Undershrub widely distributed.

L. tenella A. DC. Erect shrublet.

Cyphia triphylla Phillips. Erect twining herb. Recorded from vleis, koppies and hills. Rare.

Lobelia dregeana (Sond.) A. DC. Herb, occasionally found in depressions.

L. erinus L. Small annual herb. Grows on cultivated lands under irrigation.

L. thermalis Thunb. Decumbent herb.

x *L. tysoni* Phillips. Small herb. Occurs with grasses on level plains. J. Bidwell, 4202. (1925).

Mezleria depressa (L. f.) Presl. Prostrate herb.

Compositae.

Vernonia kraussii Sch. Bip. Shrubby herb.

Amellus strigosus Less. Prostrate herb. Grows on edges of dams near Saltpan. Frequent.

Aster barbatus (DC.) Harv. Shrublet, 6 to 8 inches tall.

A. filifolius Vent. (= *A. fruticulosus* Less.). Winter-flowering shrub.

A. muricatus Less. Common shrublet.

A. subulatus Michx. Erect herb.

Erigeron canadense L. Annual weed of cultivation.

x *E. bonariensis* L. (= *E. linifolius* Willd.). Common weed on cultivated places. D. M. Gemmell, 5816. (1948).

Nidorella hirta DC. Annual herb, grows in lands.

N. hottentotica DC. Occasional weed in lands.

N. resedaefolia DC. Common annual.

Conyza ivaefolia Less. Undershrub favouring sheltered habitats.

C. podocephala DC. Perennial herb widely scattered in sheltered situations on heavy soils.

Chrysocoma coma-aurea L. Perennial branching shrublet. Rather rare.

C. tenuifolia Berg. Common bush on overgrazed veld.

x *C. peduncularis* DC. Recorded from Bfn. G. Potts, 63. (1906).

Tarchonanthus minor Less. Tree, singly scattered on randjies.

T. camphoratus L. var. *litakunensis* DC. Tree.

Denekia capensis Thunb. Small herb. Frequently found in moist situations.

Epaltes alata Steetz. Shrub.

x *Ifloga paronychioides* (DC.) Frenzl. Minute annual one-third to half inch tall. Grows under grass and bushes on damp ground. G. Potts, 3587. (1925).

x *Lasiopogon lanatum* Cass. Minute annual herb with a woolly appearance. Grows in shade of shrubs on marshy ground. G. Potts, 2380. (1917).

Gnaphalium candidissimum Lam. Recorded from water-edges in the Rhenostersprui. Prefers wet mud.

G. luteo-album L. Herb growing in wet places in the Modder River and in vleis.

G. undulatum L. Frequent as a weed in gardens and lands.

Helichrysum argyrosphaerum DC. Perennial herb.

H. aureonitens Sch. Bip. Grows in wet spots.

x *H. caespititium* Sond. Prostrate pioneer on bare road surfaces. G. Potts, 2641. (1917).

H. capillaceum (Thunb.) Less. Grows on bare soils between boulders on hill slopes.

H. cerastioides DC. Prostrate woolly shrublet.

H. declinatum Less. (= *Amphidoxa gnaphaloides* DC.). Annual herb.

H. dregeanum Harv. & Sond. Shrublet occurring on hill slopes, etc.

H. ericaefolium Less. Ericoid herb.

H. nudifolium (L.) Less. (= *H. leiopodium* Less.). Erect herb rarely found on hill slopes.

H. paronychioides DC. Scattered on lands and disturbed places. Perennial herb.

H. pentzioides Less. Undershrub.

H. setosum Harv. var. Shrublet with large showy yellow flowers. Grows on lower hill slopes. Rare. No. 833.

H. zeyheri Less. Undershrub.

Pterothrix spinescens DC. Spinescent ericoid shrub.

Nestlera conferta DC. Erect much branched shrub.

N. humilis Less. Erect shrub growing on overgrazed turfy soils. Uncommon.

Pegollettia retrofracta (Thunb.) P. Kies. (= *P. polygalaefolia* Less.). Shrub.

Pulicaria capensis DC. Erect yellow-flowered herb.

Geigeria africana Gries. (= *G. passerinoides* Harv.). Acaulescent shrublet.

Xanthium spinosum L. Common weed in vlei lands.

x *X. strumarium* L. Weed in lands and on bare heavy soils. G. Potts, 1912. (1915).

Zinnia multiflora L. Weed of cultivation and occasionally on disturbed spots.

Z. pauciflora L. Introduced weed of cultivation.

x *Bidens bipinnata* L. Ruderal. Grows in lands and gardens. D. M. Gemmell, 5057. (1936).

B. pilosa L. Common weed.

x *B.* sp., *B. pilosa* L. x *B. chinensis* (L.) Willd. Recorded from a koppie at Bfn. G. Potts, 5058. (1931).

Cosmos bipinnatus Cav. Weed at roadsides, Glen. Very rare.

Galinsoga parviflora Cav. Common weed and ruderal.

Flaveria contrayerba Pers. Weed in lands and waste places.

Schkuhria bonariensis Hook and Arn. Common weed.

Tagetes minuta L. Common weed of cultivation.

Eriocephalus spinescens Burch. Ericoid shrub.

Lasiospermum bipinnatum (Thunb.) Druce (= *L. radiatum* Trev.). Perennial herb.

Anthemis cotula L. Erect herb, growing on disturbed places. Uncommon.

Phymaspermum parvifolium (DC.) B. & H. Valuable fodder bush occurring very sparsely on veld in southern part of this area.

Cotula anthemoides L. Weed on cultivated lands.

C. burchellii DC. Annual weed.

C. leptalea DC. Small weed growing on wet soils near dams, etc.

C. microcephala DC. Prostrate pioneer, occurs on wet disturbed places.

Cenia microglossa DC. Annual herb.

x *C. microglossa* DC. var. Annual weed of cultivation. G. Potts, 2612. (1917).

Artemisia afra Jacq. Common undershrub.

Pentzia globifera (Fenzl.) Hutch. (= *Matricaria globifera* Fenzl.). Aromatic winter annual.

P. globosa Less (= *P. virgata* Less.). Common shrublet.

P. incana O. Kuntze forma. Uncommon shrublet.

P. lanata Hutch. Erect cano-pubescent shrublet.

P. sphaerocephala DC. Erect herb occurring on hills.

Hertia ciliata (Harv.) O. Kuntze. Shrublet, 6 to 8 inches tall.

Cineraria alchemilloides DC. Grows on shady places on hill slopes. Frequent.

C. aspera Thunb. Erect herb.

x *C. geraniifolia* DC. Yellow-flowered big-leafed species recorded on red sandy soils. Collector unknown, 23. (1905).

C. lyrata DC. Annual winter plant.

x *Senecio achillaefolia* DC. Rhizomatous herb. Grows between rocks on beds of flushes. Collected by a native, Jacob, 4343. (1930).

S. burchellii DC. Annual, common in irrigated lands, etc.

x *S. erosus* L. f. Erect herb recorded from Bfn. G. Potts, 780. (No date).

S. erubescens Ait. Purple-flowered herb favouring swampy sites.

S. fraudulentus Phill. & Sm. var. *macrocephalus* Hutch. & Burtt Davy (= *S. serra* var. *macrocephalus* Hutch. & B. Davy). Erect perennial herb favouring moist sites in Themeda grassveld. Collected by J. Morris, Glen Herb. No. 834.

x *S. glanduloso-pilosus* Volkens & Muschl. Recorded from hills, Perennial herb. G. Potts, 2605. (1917).

x *S. glutinosus* Thunb. Erect herb, three feet tall. Grows in spruits. Rather rare. D. M. Gemmell, 4948. (1936).

x *S. harveianus* Macowan. Yellow-flowered herb, grows on hills. G. Potts, 492. (1915).

S. hastulatus L. Erect yellow-flowered herb.

x *S. hieracioides* DC. Occasional on bare soils on slopes of randjies. G. Potts, 1987. (1915).

x *S. inaequidens* DC. Annual herb occurring on wet situations. Suspected of causing poisoning in horses by Bloemfontein Municipality. N. Viljoen, 5990. (1951).

S. laevigatus Thunb. Common pioneer.

S. othonniformis Fourc. Herb.

S. oxyodoutus DC. Herb, occurs in shade of tree on hill slopes. Rare.

S. (= *Kleinia*) *radicans* Thunb. Succulent herb.

S. reptans Turcz. Hygrophilous herb.

S. sp. nov. aff. *S. glutinosus* Thunb. Large yellow-flowered annual herb Weed in gardens and disturbed situations. Quite common. No. 3, 508.

x *Kleinia longiflora* DC. Recorded from hills near Bfn. G. Potts, 3750. (1926).

Euryops sulcatus Harv. var. *densifolius* (Sond.) Harv. (= *E. densifolius* Sond.). Common shrub.

x *E. multifidus* (L. f.) DC. Grows on hills and koppies north of Bfn. Shrub. D. M. Gemmell, 2900. (1923).

Othonna pallens DC. Encroaching shrub.

Dimorphotheca zeyheri Sond. Poisonous perennial herb.

D. sp. prob. *D. nudicaulis* DC. Recorded from Bfn. Rare.

Garuleum pinnatifidum DC. Common shrub.

Osteospermum leptolobum (Harv.) T. Norl. Shrub.

O. muricatum E. Mey. Common woody pioneer.

O. scariosum DC. (= *Tripteris flexuosa* Harv.). Erect herb. Common on disturbed places.

O. spinescens Thunb. (= *Tripteris pachypteris* Harv.). Spinescent shrub.

Ursinia nana DC. (= *U. annua* Less). Small annual herb, grows on slopes of hills and koppies.

Arctotis staechadifolia Berg. Herb frequently found in lands, etc.

Venidium arctotoides Less. Perennial creeping herb.

V. microcephalum DC. Prostrate herb found in vleis and near dams.

Gazania jurineaefolia DC. Dwarfed herb.

G. longicapa DC. Perennial herb. Scattered in Themeda grassveld and on hill slopes.

G. longifolia Less. Herb, commonly found in valleys.

G. krebsiana Less. Grows on bare spots near the Rhenosterspruit.

G. oxyloba DC. Widely scattered perennial herb, especially on heavy soils in the valleys.

x *G. pinnata* Less. var. Recorded from Bfn. G. Potts, 37. (1905).

Berkheya epitrachys DC. Common weed.

B. kuntzei O. Hoffm. Sub-woody perennial.

B. onopordifolia (DC.) B. Davy. Common annual weed.

x *B. stobaeoides* Harv. Recorded from Bfn. D. M. Gemmell, 4594. (1935).

Platycarpha parvifolia S. Moore. Acaulescent herb.

Centaurea cyanus L. Introduced weed occasionally found in irrigated lands, Glen.

C. picris Pall. Perennial deep-rooted weed, occasionally found in lands.

Dicoma anomala Sond. Perennial herb found on rocky outcrops.

D. gerrardi Harv. Small herb favouring stony koppies.

D. macrocephala DC. Prostrate perennial, occurs on stony rises and hills.

Gerbera piloselloides Cass. Occurs on koppies in shade of trees. Frequent in shade of *Rhus* sp.

Cichorium intybus L. Weed in a garden. Uncommon.

Tolpis capense (L.) Sch. Dip. Perennial herb preferring wet situations.

Hypochoeris radicata L. Acaulescent herb. Weed in gardens.

Tragopogon porrifolius L. Broad-leaved weed.

x *Sonchus dregeanus* DC. Yellow-flowered herb. Occurs in grassveld. D. M. Gemmell, 6143. (1952).

S. nanus Sond. Acaulescent perennial. Grows on hills and slopes. Uncommon.

S. oleraceus L. Common weed of cultivation.

S. sp. cf. *S. oleraceus* L. Robust species, three feet tall. Favours water edges.

Lactuca capensis Thunb. Erect herb. Occurs in gardens.

L. dregeana DC. Herb. Frequent on wet situations.

L. scariola L. Pioneer on stream banks. Erect, herbaceous.

Taraxacum officinale (Weber) Wigg. Acaulescent herb.

CHAPTER II.

DISCUSSION AND SUMMARY.

1. DISCUSSION.

The natural veld in the central parts of the Orange Free State, as well as over the greatest part of the Union of South Africa, plays a major role in sustaining thousands of livestock. A detailed knowledge of the veld is of fundamental importance to agricultural research workers as well as to the stock farmers.

The natural veld can be studied from different points of view, e.g. physiologically, systematically, ecologically and sociologically. In this thesis the vegetation has been studied from a floristic and sociological point of view and some practical points which may be of value to farmers have also been considered.

A study of the literature on geobotanical research in South Africa has revealed that the American school has had the strongest influence on South African ecologists. Practically all South African papers on plant ecology are based on physiognomical descriptions of the vegetation. The sociological methods for the study of vegetation, as used in Europe, have not been applied in South Africa, and most of the South African papers lack detailed quantitative analysis of the vegetation.

Although this study too began as a physiognomical description of the vegetation, it was soon realised that a detailed analysis and a proper characterisation of the veld are necessary for ecological and pasture studies. The writer therefore studied some of the communities from a more basic point of view, viz. the quantitative relationships. As far as possible the method of Braun Blanquet (1932) was followed and supplemented by quantitative surveys.

Of the numerous methods devised for surveying the grassland and open veld in South Africa, Tidmarsh and Havenga's Wheel Point method was found to be the most practical and reliable. This method has the advantage that its results can be analysed statistically and it was successfully applied by the writer to grassveld and open karroid communities (Gannaveld). Not only is the percentage basal cover easily determined but this method also shows the composition of the vegetation. As this picture is of necessity incomplete the writer feels that the quantitative data obtained with the Wheel Point method should be supplemented with general field notes, especially on the occurrence of species not struck by the spokes of the wheel, on plant dispersion, vitality, height, phenology, etc. The combination of all these data gives a much more complete description of the composition and condition of the vegetation at the time of survey.

As can be seen from the tables, surveys were made on plots of varying sizes. This is a drawback in the comparison of various plots for the number of species since it can be expected that the number of species will increase with the increase in size of the plots. This was, however, fully considered when conclusions were drawn.

The quantitative analyses were started as surveys of existing experimental grazing camps which were laid out on a farming scale by the writer's predecessors at the Glen College of Agriculture. In the laying out of some of these experimental camps the homogeneity of the veld and soil were, however, not sufficiently taken into consideration. In the interpretation of the results this was borne in mind by the writer. If the experiments had been laid out with sufficient consideration of the smaller but still important differences which exist in the sociological composition of the veld, the results presented in this thesis might have been more than a description of the *status quo*. In large camps it is often impossible to have a homogeneous soil and vegetation in the camp as a whole.

In certain communities, e.g. Gannaveld, the seasonal aspect is dependent on a number of ruderals and geophytes. To obtain a reliable picture of all the associated species an area should be surveyed several times during the year, at least during spring, summer and autumn.

Reliable methods for surveying the arborescent and scrub vegetation occurring in the valleys and on the randjies are still wanted. The Estimated Frequency List method was found to be rather difficult to apply and is considered to be somewhat inaccurate. The recently devised Surveyers Chain method will probably be the best method available (Tidmarsh, personal communication).

The factors determining the distribution of *Acacia karroo*, Ganna and Grassveld communities in the valleys may be water or soil factors, or grazing practices, or even a combination of some or all of these factors. The writer is of the opinion, however, that the water factor is the most important. All evidence available seems to show that, as a result of overgrazing, *Acacia karroo* has encroached at the cost of perennial valley grasses. This could, however, not be proved definitely.

Generally a marked difference exists between the edaphic and climatic conditions as well as the vegetation on the dry northern and the moist southern slopes of the randjies. It is possible that, apart from the climatic and edaphic factors discussed in this thesis, other climatic, edaphic and even biotic factors may play an important role in determining the plant communities on the different slopes. For future work it will be necessary to determine more precisely which plant communities occur on the different slopes of the randjies.

It is clear that the two communities *Eberlanzia spinosa–Euphorbia mauritanica* and *Euryops sulcatus* var. *densifolius–Euphorbia mauritanica* show strong affinities with the flora of the karroo and differ markedly from those of the rest of the area studied. These communities occupy xeric habitats and are composed of highly adapted, drought resistant plants. Although the origin of these karroid communities in a vast Themeda grassveld area is still open to speculation, the possibility exists that these species may have been dispersed by wind, animals or man and became established in a particular area north of Bloemfontein.

The greater part of the area is grassveld. It occupies the flats, bults, vleis and parts of the edges of the valleys. Three different grassveld types are encountered which are determined principally by water conditions and differences in the soil. On heavy soils in the valleys and vleis, especially where water accumulates without the soil's becoming water-logged, the Valley–Vlei grassveld is found. On the sandy and loamy bults, flats and

plains, Themeda grassveld predominates, and on the limestone outcrops and bults, the Kalkveld community. Themeda, however, occurs in all three grassveld types.

The Valley–Vlei grassveld is characterised by the dominance of *Setaria nigrirostris*, *Eragrostis bicolor* and *Panicum stapfianum*. *Eragrostis curvula*, *Themeda triandra*, *Medicago denticulata*, *Cenia microglossa*, *Brachiaria eruciformis* and *Chloris virgata* are associated species. Well managed and rested Valley grassveld has a basal cover of up to 27 per cent, which is relatively high. Overgrazing of the valleys and vleis destroys the characteristic perennial valley grasses which are replaced by annuals and ruderals. The Valley–Vlei grassveld is high yielding and affords palatable grazing best utilized in winter and spring.

Kalkveld constitutes little of the grassveld in this area. The Kalkveld community is characterised by the following typical species: *Enneapogon scoparius*, *E. brachystachyus*, *Aristida vestita*, *Fingerhuthia africana*, *Nenax microphylla* and *Osteospermum leptolobum*. *Themeda triandra* and *Tragus koelerioides* are constantly present in this community, but are not confined to Kalkveld. Themeda on limestone is destroyed if continuously grazed by sheep and replaced principally by *Enneapogon scoparius*. Kalkveld can be utilized best as summer grazing.

Themeda grassveld is the most extensive grassveld community occurring in this area. The dominant species is *Themeda triandra* with the following as typical associated species: *Eragrostis lehmanniana*, *Tragus koelerioides*, *Aristida* spp., *Cymbopogon plurinodis*, *Heteropogon contortus*, *Digitaria* spp., etc. On well managed camps Themeda constitutes anything up to 92 per cent of the total basal cover. As a result of intensive grazing Themeda is destroyed on many farms and is replaced by pioneers, e.g. *Aristida* spp. and *Tragus koelerioides*. With sheep grazing alone there is much selective grazing, palatable perennial grasses are destroyed, and unwanted plants encroach. As shown in a previous publication (Mostert 1952) Themeda-veld, if properly managed, is nutritious and has a carrying capacity of five morgen per beast. Especially where veld hay can be cut animals can be kept in a good condition on Themeda-veld through the year. To minimize the detrimental influence of sheep grazing on the veld, cattle should be used as well.

It is very difficult to state with certainty which community is the climax on the flats and bults. It may have been a *Themeda triandra–Cymbopogon plurinodis* community in the past. Undoubtedly on numerous farms the climax community has been destroyed and replaced by sub-climax or pioneer species.

In a study of the succession on fallowed and abandoned lands it became clear that annuals and ruderals dominate during the first three years. The most common species are: *Tragus racemosus*, *Chloris virgata*, *Salsola kali*, *Tribulus terrestris* and *Nidorella resedaefolia*. From the fifth year onwards sub-climax species (usually *Eragrostis* spp.) begin to dominate. It is not certain how many years it takes before abandoned lands become covered by Themeda. As the vegetation on some of the old lands at Glen that were abandoned for 25 years is still in a pioneer-sub-climax stage, it may be many years before the succession reaches the climax. In a previous publication the writer (1953) has shown that the revegetation of old lands can be much accelerated by the sowing of seeds of sub-climax grasses.

A total of 978 plant species and varieties was collected in the area. If a floristic comparison is made with other areas in the summer rainfall region it appears that the Bloemfontein–Brandfort area is relatively rich in species. The families *Aizoaceae*, *Cruciferae*, *Chenopodiaceae* and *Solanaceae* are particularly well represented.

2. SUMMARY.

(1) The geology, topography and soils of certain parts of the Bloemfontein and Brandfort districts are briefly described.

(2) An account is given of the climate of the area with special reference to temperature and rainfall.

(3) In accordance with varying topographical, edaphic and climatic conditions the vegetation of the area is divided into the following types:—

(*a*) The Aquatic and sub-aquatic vegetation.

(*b*) The Valley Acacia Bush community.

(*c*) The vegetation of the Randjies.

(*d*) Grassveld. On account of varying soil types the grassveld is divided into (i) Valley-Vlei grassveld, (ii) Themeda grassveld and (iii) Kalkveld.

(4) The most important field methods (for veld studies) used in South Africa are discussed. Tidmarsh and Havenga's Wheel Point method was found to be a promising method for surveying grass and open communities, and was used to survey the Grassveld and Gannaveld communities which received special attention. The vegetation on the randjies was recorded more or less according to the Estimated Frequency List method. The data on the Bush community, hydrophytes, succession, etc., were based principally on observations and estimates.

(5) Permanent springs are absent in the area and the watercourses are dependent on the irregular rainfall. An account is given of the submerged hydrophytes, floating aquatics, reed-sedge communities and of the semi-aquatic vegetation occurring along the watercourses. The floras of the streamsides, dams, pans, irrigated lands and regularly flooded situations are discussed and compared with those of the Potchefstroom area. True hydrophytes are poorly represented, and semi-aquatic vegetation is usually restricted to narrow strips on the edges of watercourses, dams, etc. As a result of heavy grazing and trampling the vegetation of the vleis and streambanks has been much modified and erosion has been intensified.

(6) The vegetation of the valleys is divided into three distinct types, viz. (*a*) Valley Acacia Bush community, (*b*) Gannaveld and (*c*) Valley grassveld. The last two communities occur between the trees. Moisture determines the distribution and development of these types. The *Acacia karroo*-community and as its undergrowth are discussed. To determine the composition of the Ganna community four botanical surveys were made and analysed.

(7) The edaphic and climatic conditions found on the southern and eastern and on the northern and western randjie slopes are discussed. The vegetation of the randjies is classified as follows:—

(*a*) *Karroid communities.*—Some of the randjies north of Bloemfontein are covered by a karroid vegetation which differs markedly from the vegetation on the rest of the randjies in

this area. The two typical karroid communities, viz. *Eberlanzia spinosa–Euphorbia mauritanica* and *Euryops sulcatus* var. *densifolius–Euphorbia mauritanica* communities are described and discussed.

(*b*) *The vegetation on the rest of the randjies.*—Botanical surveys of the vegetation on the northern and southern slopes of a koppie near Glen, on the northern and southern slopes of ridges near Glen and Karree, and on a hill at Mazelspoort were made according to the Estimated Frequency List method. An account is given of the flora on the different slopes, the tops and the kloofs, as well as a discussion of the most important species found on the randjies.

(8) Grassveld is the most extensive veld type found in this area; it occupies approximately 70 per cent of the total area. Three types can be distinguished, viz:—

(*a*) *Valley–Vlei grassveld.*—The composition and basal cover of the Valley–Vlei grassveld community was analysed. This community is characterised by the dominance of *Setaria nigrirostris*, *Panicum stapfianum* and *Eragrostis bicolor*. The species characteristic of the valleys and vleis are discussed, as well as the composition of an overgrazed valley camp.

(*b*) *Themeda grassveld.*—The results of 12 botanical surveys were analysed and a characterisation of the composition of this most important community is given. The most abundant species are discussed. Results from overgrazed as well as from well managed and rested camps are analysed. The effect of cattle and sheep grazing on Themeda-veld was studied.

(*c*) *Kalkveld.*—The results of six botanical surveys were used to characterise the composition of the Kalkveld community. The most typical Kalkveld species are indicated. Botanical surveys of cattle and sheep grazed camps, are discussed. The detrimental effect of continuous sheep grazing is demonstrated.

(9) Retrogression in Themeda grassveld is discussed. The vegetation on camps in the climax, sub-climax and pioneer stages is described. Creeping therophytes, bulb geophytes and shrub phanerophytes which occur as pioneers are mentioned.

The plant succession was studied on old lands, abandoned for 4, 5, 15 and 25 years. During the first two years after fallowing, pioneer plants, mostly annuals and ruderals, dominate. During the third and fourth years *Cynodon dactylon* and *Aristida* spp. become more conspicuous and the sub-climax species (usually *Eragrostis* spp.) appear. From the fifth year onwards the sub-climax species dominate and it normally takes many years before they are succeeded by the climax *Themeda triandra*. The succession is much slower on heavy than on lighter soils.

(10) A floristic analysis and a check list of 978 species and varieties occurring in this area are given, with brief notes on distribution, ecology, etc.

A brief floristic comparison is made between the Bloemfontein–Brandfort area and other areas surveyed in the summer rainfall region.

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ILLUSTRATIONS

Photographs by the Author

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FIG. 1.—A patch of *Haemanthus amarylloides* in flower in the valley of the Modder River near Glen Station. Nov. 1952.

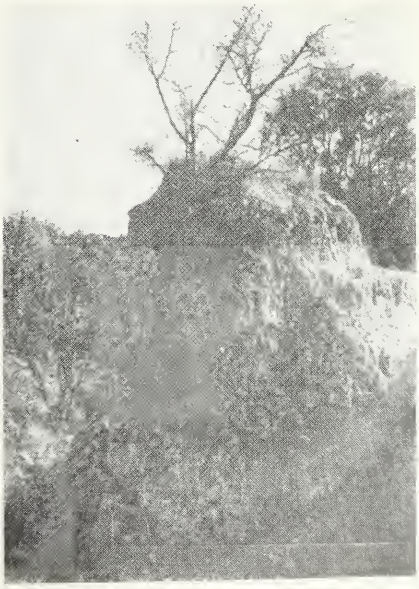


FIG. 2.—A *Ziziphus mucronata* tree on the side of a donga at Glen. Note exposed root system. 30th June, 1952.

FIG. 3.—A dense clump (38 yards in circumference, 12 yards in diameter) of *Lycium hirsutum* on a limestone bult at Glen. 30th June, 1952.

FIG. 4.—*Dimorphotheca zeyheri* in flower in Ganna-community, Camp F. 16, Glen College of Agriculture. Background: A. karroo; foreground: *Salsola glabrescens*.

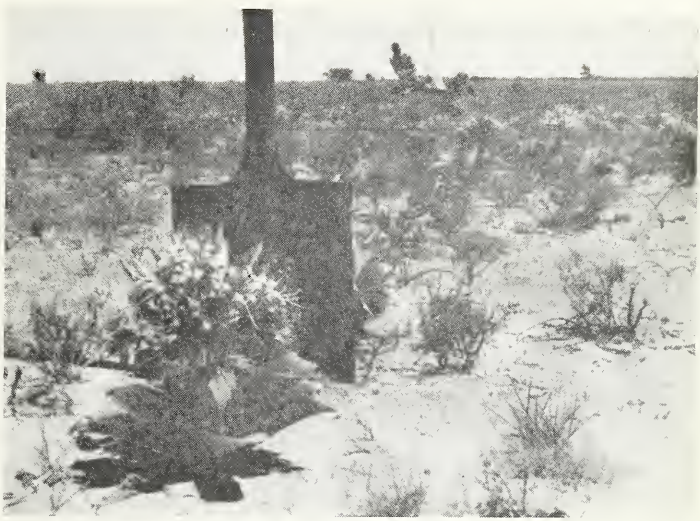


FIG. 5.—*Ammocharis coranica* in flower on heavy soil near the Modder River on the farm Glen Lyon. Associated with a sparse stand of *Salsola glabrescens*. 24th November, 1953.

FIG. 6.—*Eberlanzia spinosa* in flower on a rocky bult north of Tafelkop. Right foreground: Large flat, bare, rock surfaces. A few flowers of *Heliophila suavissima* can be seen protruding on the left and right sides of the *Eberlanzia*-bush. 24th November, 1953.

FIG. 7.—Northern slope of the koppie surveyed on the farm Glen Lyon. Note gregarious patches of *Rhus ciliata*. 10th April, 1953.

FIG. 8.—Southern slope of a hill on the farm Tafelkop. The trees are mostly *Olea africana, Rhus erosa* and *Buddleja salicifolia*. 10th April, 1953.

FIG. 9.—South-facing slope of a hill (and a kloof on the left) on the farm Glen Lyon, which is densely covered by *Olea africana* and *Buddleja salicifolia*. 10th April, 1953.

FIG. 10.—A dense bush community (mostly *Olea africana*) on the southern slope of a small hill five miles north-east of Glen. 7th March, 1953.

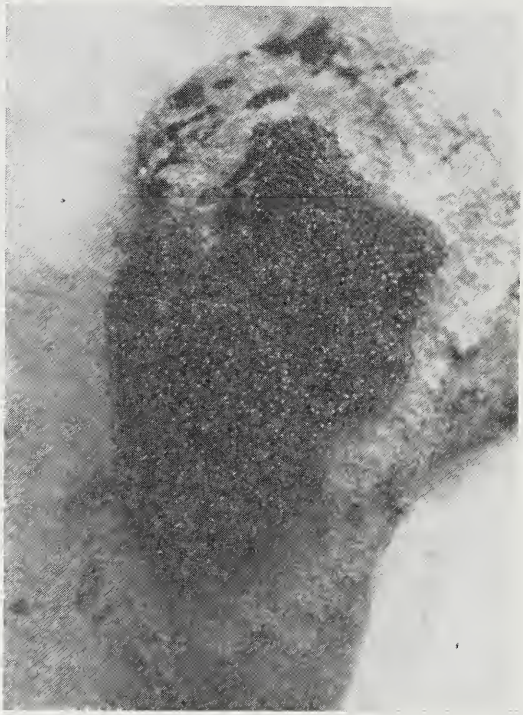


FIG. 11.—A moss covering part of a stone found in a shady spot on the eastern slope of a hill on the farm Glen Lyon. December, 1951.

FIG. 12.—Typical shape of *Olea africana*. Near Karree Station. 7th March, 1955.

FIG. 13.—*Buddleja salicifolia* in flower on the slope of a hill near Karree. 7th March, 1955.

FIG. 14.—A dense stand of *Setaria nigrirostris* in a vlei-like part of camp A. 4 at the Glen College of Agriculture. Background: *Acacia karroo* community. 3rd February, 1951.

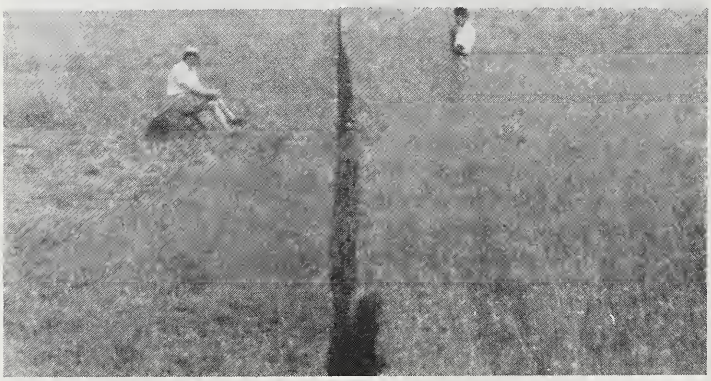


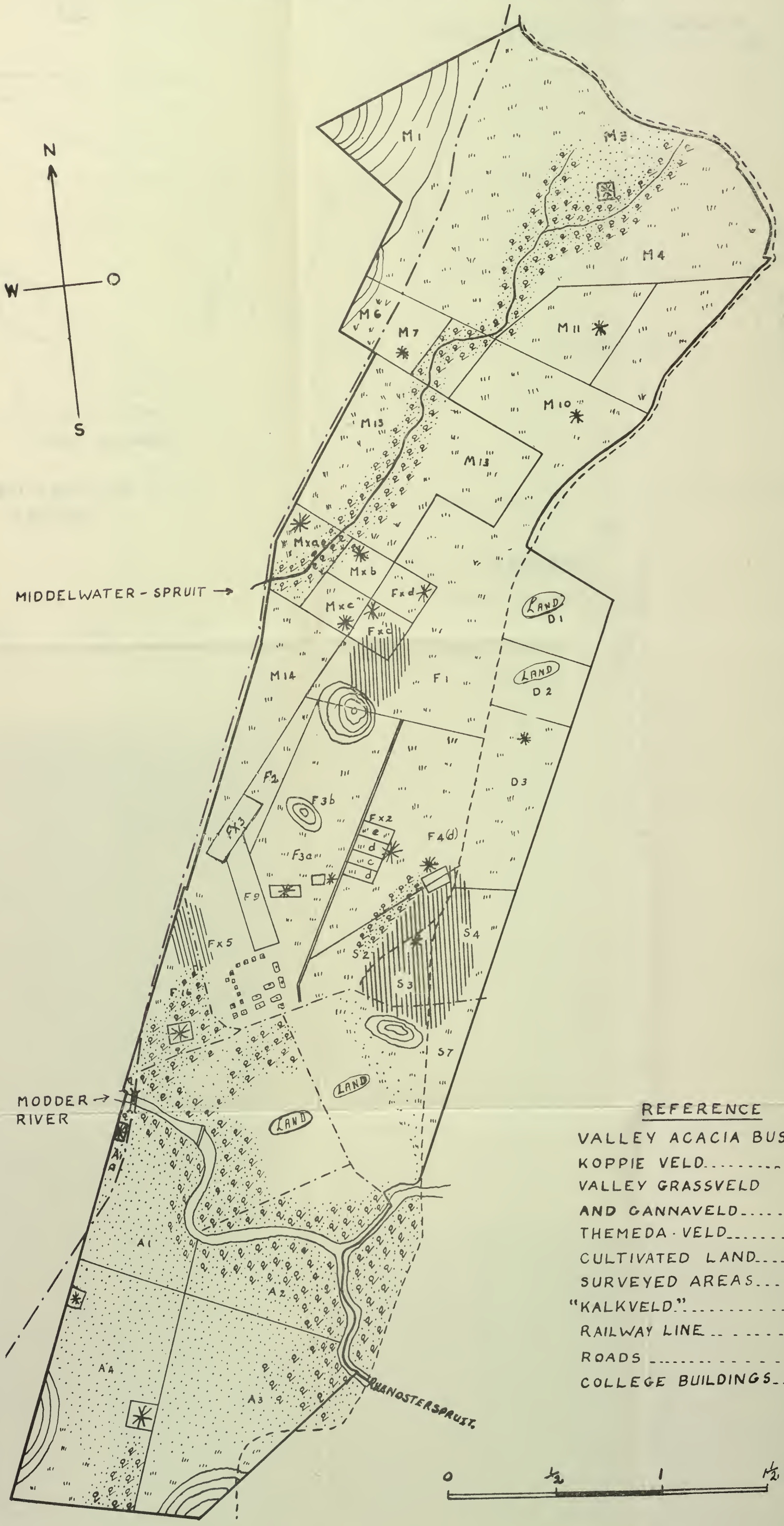
FIG. 15.—A fence separating well rested Themeda-veld (right side) from overgrazed Themeda-veld in which pioneers dominate (left). On a farm five miles east of Karree. 7th March, 1955.

FIG. 16.—Dense stand of Themeda in the Arboretum plot, Glen. Left foreground: Camp F. 3A which was heavily grazed by cattle. 13th February, 1953.

FIG. 17.—*Homeria pura* in flower on an unploughed maize land. Taken on a farm near Saltpan. 24th October, 1953.

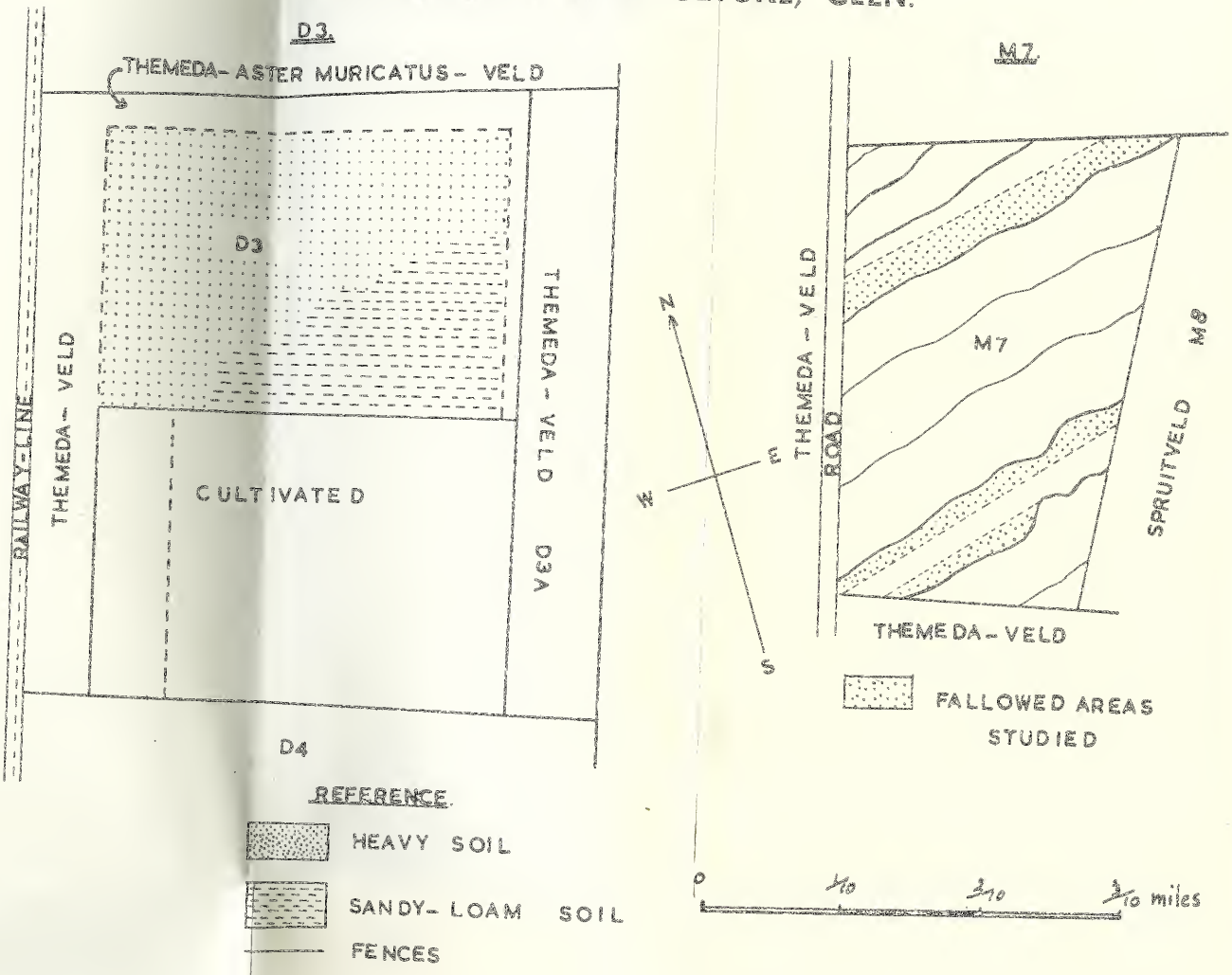
MAP No. 1.

MAP SHOWING VELD TYPES AND SURVEYED CAMPS AT THE GLEN COLLEGE OF AGRICULTURE.



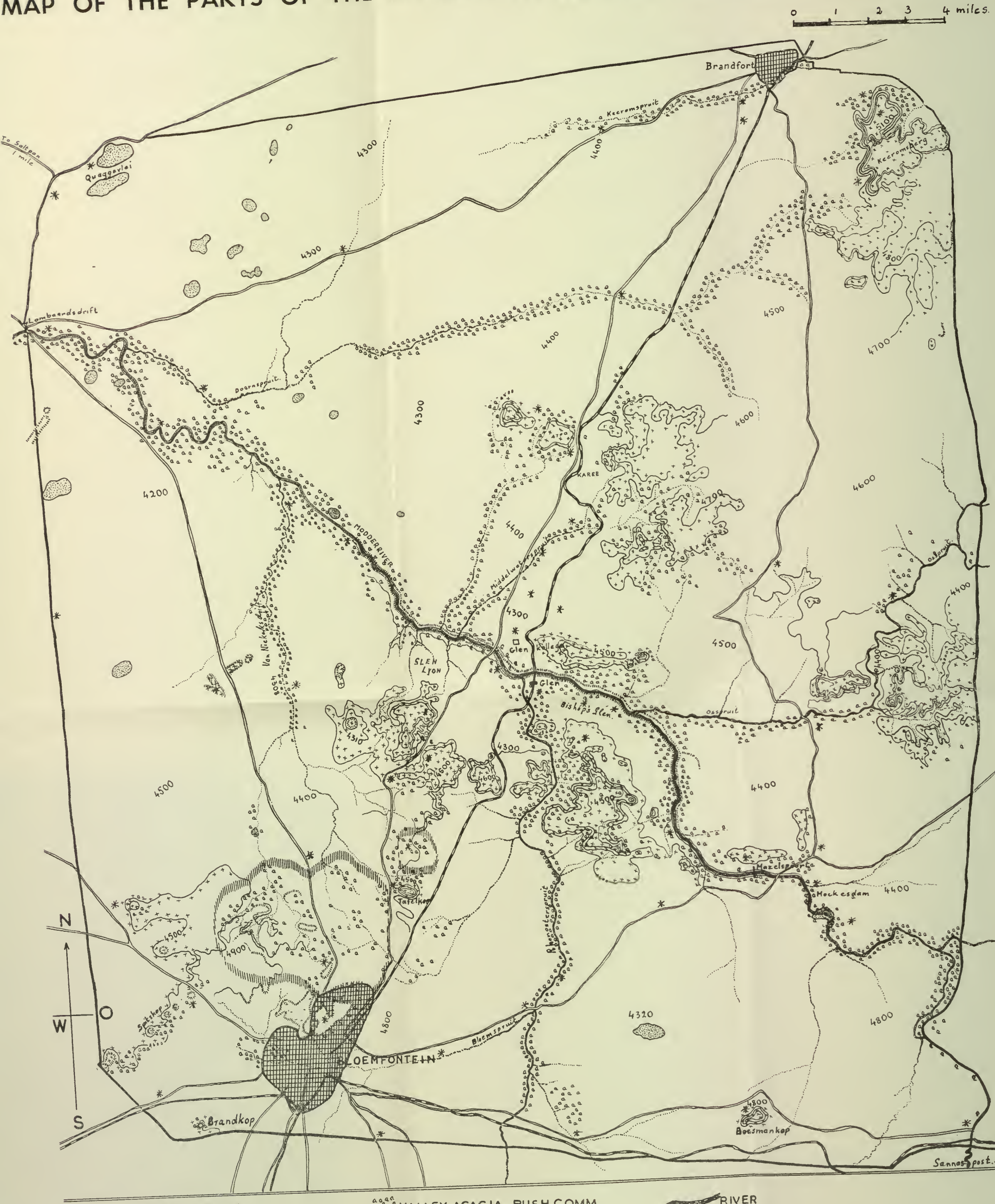
MAP No. 2.

MAP SHOWING THE SITUATION OF LAND D3 AND M7 AT THE COLLEGE OF AGRICULTURE, GLEN.



MAP No. 3.

MAP OF THE PARTS OF THE BLOEMFONTEIN-BRANDFORT DISTRICTS STUDIED.



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